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EVALUATION OF NATIONAL BOILER INVENTORY

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OCTOBER 1975

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16. ABSTRACT The report gives a compilation of the boiler inventory for the Continental United States, using available data sources. Primary sources included the National Emissions Data Bank data, American Boiler Manufacturers Association boiler sales data, and earlier reports to the EPA. Residential, commercial, industrial, and utility boilers are included. Results are presented as: cumulative boiler installed capacity and cumulative actual boiler use (by fuel and total), both plotted against boiler size; cumulative SO2, NOx, and particulate emissions (by fuel and total), plotted against boiler size; and tables of boiler number count, boiler installed capacity, boiler actual use, SO2 emission, NOx emission, and particulate emission, by boiler size and fuel.

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Population (Statistics)		Commercial Boilers	12A	
Coal	Dust	Industrial Boilers	21D	11G
Emission	Sulfur Dioxide	Residential Heaters		
Fuel Oil		Utility Boilers		
		Particulate		

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October 10, 1975

INTRODUCTION

The aim of this program is to provide a data-base of boilers and warm air furnaces in terms of a "population-characteristics matrix", so that (1) estimates can be made of national impacts of pollutants from various sizes and types of boilers, and (2) selections can be made of representative units (from a pollutant standpoint) for tests that would cover the major boiler and warm air heat sources in the chosen range.

As part of another program, Battelle-Columbus prepared an analysis of the population of industrial boilers,(based primarily on NEDS data and American Boiler Manufacturers Association (ABMA) sales data) which included a summary by boiler sizes and types[1]. In the present task, that earlier industrial boiler analysis is extended to include boilers of larger and smaller capacities. Thus, all boilers, the nominal utility, industrial, commercial, and residential size ranges, are included in one boiler inventory and the total distribution of steam and hot water boilers, plus hot air furnaces, are described in a relatively uniform manner over the entire range of boiler capacities. Output of the task includes tabular distributions of boiler nmmber count, boiler installed capacity, and actual boiler use. Further, the boiler inventory developed on this program is subdivided into various size, boiler type, and fuel classes for convenient analysis of pollutant emissions. Finally, the total emission output of various sizes of boilers are derived from the distribution of the boiler fuels, boiler uses, and published emission factors.

The primary output of this study consists of Figures 5 through 9 as follows:

Figure 5. Cumulation plot of total installed boiler capacity versus boiler design firing rate

Figure 6. Cumulative plot of actual boiler use versus boiler design firing rate

Figure 7. Cumulative plot of SO_2 emissions for actual boiler use versus boiler design firing rate

Figure 8. Cumulative plot of NO_x emissions for actual boiler use versus design firing rate

Figure 9. Cumulative plot of particulate emissions for actual boiler use versus design firing rate.

DEFINITIONS

Several terms that are used repeatedly in this report should be defined to insure proper interpretation of the report and results. These are:

Design firing rate -- the input firing rate of the boiler when operating at rated load

Total installed capacity -- the sum of the design firing rates of all boilers within a group of boilers

Annual load factor -- the annual fuel consumption divided by design firing rate times hours per year

Average hourly fuel consumption or actual boiler use (for a group of boilers) -- product of total installed capacity and annual load factor (equivalent to annual fuel consumption divided by number of hours in a year).

Conversion Factors

10^6 Btu/hr (firing rate) = 700 lb/hr of steam (for 75 percent boiler efficiency)

= 0.10 megawatt, electrical (for 34 percent station efficiency)

1.0 megawatt, electrical = 10^7 Btu/hr firing rate (for 34 percent station efficiency).

CLASSIFICATION OF POPULATION DISTRIBUTION

In general, one would like to maintain as few classifications as possible in any analysis to reduce the amount of material that must be comprehended, and to increase the count number in each classification, and, thus, the accuracy of any deductions about the classification. On the other hand, any factor which might cause a decided change in pertinent characteristics of a classification must be used to split the classification. Furthermore, each classification should not cover initially too large a range in sizes, because there are often differences in boilers that result from size alone, e.g., construction method, packaged versus field erected, and these differences may affect boiler populations (two package boilers may be installed instead of one field-erected unit due to lower cost). For the present study, as a result of the viewpoint just presented, a consideration of the results of preliminary analyses of the available data, and the results presented in Reference 1, the following classifications have been considered.

Division by Size

In Reference 1, in classifying boiler data as a function of boiler size, the total population of industrial boilers was divided into 5 size ranges (in lb/hr of steam generated) as follows: 1^+ to 2×10^4, 2^+ to 5×10^4, 5^+ to 10×10^4, 1^+ to 2×10^5, and 2^+ to 5×10^5. To maintain consistency in form, the lower limit in each range, including the lowest range, starts slightly above the division, e.g., 10,001, 20,001, etc. Divisions at these points were found to be consistent with the literature. In the present study, these boiler capacities are converted to Btu/hr and the range is extended to larger boiler sizes to cover the entire range of NEDS data[2]. (Residential units are treated separately in a later section of the report.)

Table 1 lists the size classifications used to cover the entire range of NEDS data. It is seen that each size classification includes boilers covering a size range of 2:1 or 2.5:1. It is obvious that boiler size increments of 2.5:1 would contain more boilers than size increments of 2.0:1. Thus, some adjustment must be made to equate all size increments for some calculations and plots in subsequent sections of the report, that is, to adjust all size increment ranges to the equivalent of a uniform boiler size increment, say 2.0:1. This might be done by multiplying the boiler data in the 2.5:1 size ranges by 0.80 before plotting (since the 2.0:1 size range is only 0.80 times as large as the 2.5:1 size range). However, a more mathematically proper method of making this adjustment is on a log basis rather than on a linear basis. The normalizing ratios listed in Table 1 were calculated on a log basis, in the same manner as log mean temperature differences are calculated for heat transfer problems. In figures presented later in this report where normalized boiler data are plotted, the actual values plotted are the real boiler data divided by the proper normalizing ratios. Therefore, Table 1 lists, in addition to the nominal boiler ranges, the log mean boiler size and the normalizing ratios for each size range*. To include the residential data, the size range in Table 1 is extended downward to a design capacity of $2^{+} \times 10^{4}$ Btu/hr.

Division by Use

Four boiler use categories might be considered, residential, commercial, industrial, and utility. It is quite common to use an arbitrary design capacity as the dividing line between use categories, as shown in Table 2[1,3]. However, another recent study[4] has shown that the annual load factor is more dependent on actual boiler use than on design size, or even fuel. For example, commercial boilers of a given size have low annual load factors (since they are used primarily for heating during the winter) while industrial boilers of the same size have high annual load factors (since they are used all year for generating process steam). As a result, if a division is not made on the basis of actual use, the annual load factors will not be correct, with a resulting possible misinterpretation of results.

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* The minimum number in NEDS data is 1×10^{6} Btu/hr. Assuming a value of 1 corresponds to a rounded off value 0.5 to 1.4, and so forth, actual ranges are determined and used in computing log mean size and normalizing ratio.

TABLE 1. BOILER SIZE RANGES USED TO CLASSIFY NEDS DATA

Size Identification	Nominal Range of Boiler Design Firing Rates Included in This Size Classification, Btu/hr (input)	Actual Boiler Size Ranges Included in This Size Classification in NEDS Data, Btu/hr		Log Mean Size,(d) Btu/hr (input)	Normalizing Ratios (e)
		Min(c)	Max(c)		
Size 1*(a)	1×10^6	0.5×10^6	1.4×10^6	0.837×10^6	1.485
1(b)	$1^+ - 2 \times 10^6$	1.5×10^6	2.4×10^6	1.897×10^6	0.678
2	$2^+ - 5 \times 10^6$	2.5×10^6	5.4×10^6	3.674×10^6	1.111
3	$5^+ - 10 \times 10^6$	5.5×10^6	10.4×10^6	7.563×10^6	0.919
4	$1^+ - 2 \times 10^7$	10.5×10^6	20.4×10^6	1.464×10^7	0.958
5	$2^+ - 5 \times 10^7$	20.5×10^6	50.4×10^6	3.214×10^7	1.298
6	$5^+ - 10 \times 10^7$	50.5×10^6	100.4×10^6	7.121×10^7	0.991
7	$1^+ - 2 \times 10^8$	100.5×10^6	200.4×10^6	1.419×10^8	0.996
8	$2^+ - 5 \times 10^8$	200.5×10^6	500.4×10^6	3.167×10^8	1.319
9	$5^+ - 10 \times 10^8$	500.5×10^6	1000.4×10^6	7.076×10^8	0.999
10	$1^+ - 2 \times 10^9$	1000.5×10^6	2000.4×10^6	1.415×10^9	1.000
11	$2^+ - 5 \times 10^9$	2000.5×10^6	5000.4×10^6	3.163×10^9	1.322
12	$5^+ - 10 \times 10^9$	5000.5×10^6	$10{,}000.4 \times 10^6$	7.072×10^9	1.000
13	$1^+ - 2 \times 10^{10}$	$10{,}000.5 \times 10^6$	$20{,}000.4 \times 10^6$	1.414×10^{10}	1.000
(14)	$> 2 \times 10^{10}$	Not Used		Not Used	(1.322)

(a) Size 1* does not refer to a range, but a specific set of data with the minimum labeled capacity in the NEDS data of 1×10^6 Btu/hr.

(b) Because NEDS data are recorded in the incremental values of 1, 2, 3, ... $\times 10^6$ Btu/hr, this set of data turns out to contain only boilers with labeled capacities of 2×10^6 Btu/hr.

(c) To accuracy of 0.1×10^6 Btu/hr.

(d) Square root of product of maximum size in range and minimum size in range.

(e) Log of ratio of maximum size in range to minimum size in range, divided by log 2.

Division by Fuel Type

The fuel divisions of main interests to this project are coal, residual oil, distillate oil, and gas. However, because of the interest in pollutants (which vary with firing method), the coal boilers are split into pulverized fuel and cyclone in one classification, and all other systems (stoker types) in the second classification. An examination of the preliminary runs also showed that by-product gas data appeared to be anomalous. Therefore, the gas data are divided into two classes with natural gas and liquified petroleum gas (LPG) in one classification and by-product gas (refinery off-gases, coke oven gases, etc.) in the other. This results in six fuel categories, as shown in Table 3. In the residential category, natural gas and LPG are considered separately.

TABLE 2. COMPILATION OF USE CATEGORIES WITH ARBITRARY NOMINAL RANGES OFTEN USED

Use Category	Design Firing Rate, Btu/hr
Utility	$> 5 \times 10^8$
Industrial	$10^7 - 5 \times 10^8$
Commercial	$3.3 \times 10^5 - 10^7$
Residential	$< 3.3 \times 10^5$

TABLE 3. COMPILATION OF FUEL TYPES OR BURNING TECHNIQUES

Pulverized coal and cyclone
Stoker and other coal not in item above
Residual oil
Distilled oil
Natural gas and liquified petroleum gas (LPG)
Other gases not in item above (primarily by-product gases)

Choice of Year

The aim of this program was to develop a consistent distribution of boilers and warm air heaters over a wide range of firing rates at one recent time. The only available relatively complete boiler count is the NEDS data[2], which were obtained principally in 1971. The other major sources of data are the Midwest Research Institute report on pulverized coal-fired boilers[5], the ABMA data on boiler sales (available on an annual basis since 1965)[6], and U.S. Department of Commerce data on boiler sales[7]. Since these data must be summed with an extrapolation back in time, the enumeration time is arbitrary. Therefore, 1971 was chosen as the time of reference.

Extrapolation to any arbitrary later year than 1971 can be made by use of growth rates reported in current literature (or, in some categories, sales data minus retirement data). However, because of the large installed capacity compared to yearly sales, there will be little change in relative distribution among categories over a few years. Thus, for the main aims of this report, it was not necessary to carry out such an extrapolation.

ANNUAL LOAD FACTOR

An important item in estimating actual boiler use and emissions is the annual load factor. The annual load factor was computed for each boiler for which NEDS data were available by dividing the total fuel heat input rate per year by the design firing rate and the number of hours per year. In a number of instances (about 20 percent) the resulting value was greater than unity, occasionally by a considerable amount. This indicated some error in these data. For these boilers an annual load factor of 1.05 was arbitrarily assigned. This will result in some overestimation of actual boiler use. However, neglect of these units will result in too low of values for boiler capacity, fuel use, and pollutant emissions. Also, some boilers are fired at above the design rate. Comparison of the portion of the data developed for Reference 4 using the 1.05 load factor with the data of Reference 8 indicates a difference of about 5 percent.

Next, for each category defined by size class, use, fuel classification, and sulfur content (in two ranges -- less than or equal to 1 percent, and greater than 1 percent), an average annual load factor was computed. Within each category, the number-of-boiler weighting system* was used rather than design firing rate; the increment of design firing rate within each category is sufficiently small, however, that the choise has no significant effect.

An examination of the annual load factor value for each boiler category led to the conclusion that, in most instances, the annual load factor was not a function of design firing rate of the boiler, within the accuracy to which it could be determined. As a result, average values of annual load factor for broader categories of boilers were determined as shown in Table 4. It was possible to obtain each annual load factor for broader categories of boilers by either number weighting or total-installed-capacity weighting of the annual load factors for each subcategory. On the basis that if all boilers were counted and data were available to determine the annual load factor for every boiler, the total-installed-capacity-

---

* Sum of annual load factors for all boilers in a size class divided by the number of boilers in that size class.

TABLE 4. ANNUAL LOAD FACTORS AS A FUNCTION OF USE AND FUEL TYPE, BASED ON NEDS DATA

	Commercial[b]	Industrial	Utility
Stoker coal[a]	0.305	0.426[c]	0.479
Pulverized coal and cyclone	0.424	0.524[d]	0.423
Residual oil	0.245	0.368	0.429 (low sulfur oil)[f,g] 0.647 (high sulfur oil)
Distillate oil	0.206	0.330[e]	0.130[h]
Natural gas and LPG	0.318	0.518	0.474
Gases other than natural gas	--	0.630	(i)

(a) Stoker coal includes all coal firing except pulverized coal and cyclone.

(b) For design firing rates of $1^{+} \times 10^{6}$ to 5×10^{8} Btu/hr. Value ranges from 0.01 to 0.16 for few boiler data above this design size range.

(c) For design firing rates up through 5×10^{8} Btu/hr. For the few few boilers above, use 0.268.

(d) For design firing rates up through 5×10^{8} Btu/hr. For boilers above, use 0.580.

(e) No data for boilers with design firing rates above 5×10^{8} Btu/hr.

(f) Use industrial value for boilers with design firing rates up to 5×10^{8} Btu/hr.

(g) Low sulfur oil is ≤ 1 percent sulfur, high sulfur is > 1 percent sulfur.

(h) All low sulfur oil.

(i) Very sparse population; suggest using industrial value.

weighted basis would be the correct one to use to compute total emissions, the total-installed-capacity basis was used for the computation.

There are no NEDS data from which the annual load factor for the residential class may be obtained. The Walden report[9] gives a range of values from 0.05 for Florida to 0.31 for Maine, with an indicated average of 0.20. No differentiation on fuel type is recorded.

To summarize, for most practical purposes, for the range of design firing rates considered herein, from 10^6 Btu/hr through 2×10^{10} Btu/hr, the parameters that fix the annual load factor are the category of use and the type of fuel. The annual load factor for commercial use runs from 0.6 to 0.8 of the annual load factor for industrial use. The utility values are closer to the industrial, but there are still variations. It follows then that, as boiler size increases and the primary boiler use shifts from residential to commercial to industrial to utility application, the overall annual load factor will increase; this explains past observations indicating annual load factors as varying with design firing rate.

Relationship of Annual Load Factors and Sulfur Content of Fuel

The annual load factor was used primarily for estimating emissions. Sulfur content of the fuel is another factor affecting SO_2 emissions. Hence, the correlation between sulfur content and use factor was examined. Only residual oil-fueled boilers with design firing rates above 5×10^5 Btu/hr (mostly utility boilers) showed a significant difference in use factors associated with fuels of different sulfur controls. The load factor values for all boiler categories are shown in Table 4.

TABULATION OF BOILER POPULATION

The boiler population is built up in four different ways.

(1) It is assumed that the NEDS data has the total count on boilers with design firing rates above 5×10^8 Btu/hr, and on utility boilers. (NEDS data on boiler count and design firing rate for all boiler size ranges are given in Table 5.*)

(2) For boilers with design firing rates in the range of 10^7 through 5×10^8 Btu/hr; values from the prior boiler study were adjusted to include hot water boilers and were used in this study. (These values are presented in Table 6.) The distribution of this total boiler population among the fuel and use categories are based on the NEDS data of Table 5. NEDS data are incomplete for boilers in this size range. Hence, ABMA sales data were used to estimate total capacity in the various size categories. Two basic approaches for making these distributions are possible, either (A) to distribute the ABMA data into fuel and use categories according to the NEDS data, or (B) to adjust the NEDS data by a conversion factor derived by comparing NEDS data with ABMA sales data for the various size categories**. The latter approach was used. The conversion factor is given in Figure 1. Figure 2 shows total installed boiler capacity (by boiler-size categories) as a function of design firing rate for ABMA data and NEDS data. Figures 1 and 2 are discussed in detail in Appendix A.

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* One is not to infer the degree of accuracy by the lack of rounding off of number counts and capacity summations. It was merely more convenient in handling the data not to continually round off the values. As will be seen from the discussion, something like ± 10 percent might be a more reasonable order of accuracy.

** The conversion factor approaches 1.0 for boilers with firing rates above 7×10^8 Btu/hr (showing NEDS data are relatively complete for the larger boilers); it is as low as 0.01 for boilers with firing rates of 10^6 Btu/hr (indicating only 1 percent of these boilers are included in the NEDS data).

TABLE 5. NUMBER COUNT OF BOILERS AND TOTAL INSTALLED CAPACITY (10^6 BTU/HR) OF NEDS DATA (CORRECTED FOR MISSING STATE DATA)[a]

	Design Firing Rate, Btu/hr														
	Size 1^+: $1x10^6$			Size 1: $-2x10^6$			Size 2: 2^+ $-5x10^6$			Size 3: 5^+ $-10x10^6$			Size 4: 1^+ $-2x10^7$		
	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.
Stoker coal	70	25	1	31	18	1	79	63	6	144	120	3	132	192	14
	70	25	1	62	36	2	322	279	26	1,202	948	17	2,054	3,105	244
Pulverized coal	0	4	0	1	7	0	0	11	0	1	12	0	6	41	2
	0	4	0	2	14	0	0	41	0	7	95	0	87	664	28
Residual oil	75	115	4	32	82	7	126	369	7	146	514	12	251	714	17
	75	115	4	64	164	14	486	1,474	32	1,189	4,110	82	3,886	10,951	282
Distillate oil	285	202	2	124	144	4	183	268	14	112	176	5	82	169	5
	285	202	2	248	288	8	693	1,043	58	839	1,379	36	1,138	2,575	90
By-product gas	0	6	0	0	8	0	0	14	0	0	9	0	0	8	0
	0	6	0	0	16	0	0	49	0	0	80	0	0	126	0
Natural gas	166	226	1	72	161	2	98	433	9	110	477	11	94	622	33
	166	226	1	144	322	4	386	1,702	35	888	3,750	78	1,471	9,582	489

(a) New York data and part of West Virginia data were not complete on NEDS computer tapes available for this project. Hence, the available NEDS data were corrected on the basis of fuel consumption.

TABLE 5. (Continued)

	Design Firing Rate, Btu/Hr														
	Size 5: 2^+ -5×10^7			Size 6: 5^+ -10×10^7			Size 7: 1^+ -2×10^8			Size 8: 2^+ -5×10^8			Size 9: 5^+ -10×10^8		
	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.
Stoker coal	200	490	39	111	519	67	24	328	117	10	118	58	0	15	5
	6,735	17,469	1,482	8,121	38,108	5,546	3,105	46,925	17,301	2,873	33,814	16,503	0	11,071	3,005
Pulverized coal	19	70	14	11	97	19	8	208	81	0	165	302	0	51	235
	625	2,679	593	831	8,144	1,549	1,137	30,679	12,517	0	49,927	103,282	0	33,022	168,744
Residual oil	366	961	53	205	589	82	77	379	168	31	214	243	4	44	163
	12,358	32,136	2,030	14,523	43,496	5,497	10,666	54,279	25,930	9,757	65,013	74,605	4,209	30,273	111,307
Distillate oil	84	163	5	40	67	14	21	58	43	13	22	67	3	3	33
	2,576	5,332	165	2,930	5,264	1,070	3,136	8,358	6,238	4,375	6,530	20,949	1,907	2,492	21,735
By-product gas	0	33	0	0	56	0	0	70	0	0	45	4	0	26	0
	0	1,341	0	0	4,001	0	0	9,235	0	0	14,386	1,496	0	16,554	0
Natural gas	130	950	56	74	712	83	51	468	181	27	243	333	5	75	241
	4,127	32,600	1,950	5,838	51,544	6,161	6,927	69,656	27,733	9,044	73,780	108,281	2,794	48,794	169,221

TABLE 5. (Continued)

	Design Firing Rate, Btu/hr														
	Size 10: 1^{+} -2×10^{9}			Size 11: 2^{+} -5×10^{9}			Size 12: 5^{+} -10×10^{9}			Size 13: 1^{+} -2×10^{10}			Size 14: $\geq2\times10^{10}$		
	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.
Stoker coal	0	5	2	0	2	2	0	0	0	0	0	0	0	0	0
	0	6,851	3,123	0	7,600	6,132	0	0	0	0	0	0	0	0	0
Pulverized coal	0	10	266	0	5	125	0	1	53	0	0	2	0	0	4
	0	16,019	376,851	0	11,945	378,536	0	5,068	327,022	0	0	22,466	0	0	-
Residual oil	0	12	83	0	1	43	0		5	0	0	0	0	0	0
	0	17,450	114,113	0	3,020	128,886	0	0	26,906	0	0	0	0	0	0
Distillate oil	0	0	3	0	1	1	0	0	1	0	0	1	0	0	0
	0	0	4,129	0	2,240	2,854	0	0	5,184	0	0	13,070	0	0	0
By-product gas	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	5,604	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural gas	4	32	174	1	11	80	0	5	17	1	4	1	1	2	1
	6,301	46,063	242,621	2,626	28,908	247,992	0	38,964	101,915	10,350	61,550	10,957	-	-	-

TABLE 6. COMPILATION OF TOTAL INSTALLED CAPACITIES IN 1971[1]
In Units of 10^9 Btu/Hr

	Design Firing Rate, Btu/hr			
	Size 4: 1^+ -$2x10^7$	Size 5: 2^+ -$5x10^7$	Size 6: 5^+ -$10x10^7$	Size 7: 1^+ -$2x10^8$
Gas and oil	453.5	460.0	542.8	340.7
Pulverized coal and cyclone	0.5	3.6	8.9	54.6
Stoker	5.1	24.3	56.8	67.9
Coal total[a]	5.6	27.9	65.7	122.5
Coal only, exclude multiple fuel[a]	5.4	24.8	55.1	94.3
TOTAL	459.1	487.9	608.5	463.2

(a) The present study classified on the basis of the major fuel usage. Thus, the numbers would fall between these two if the same assumptions were made as in Reference 1.

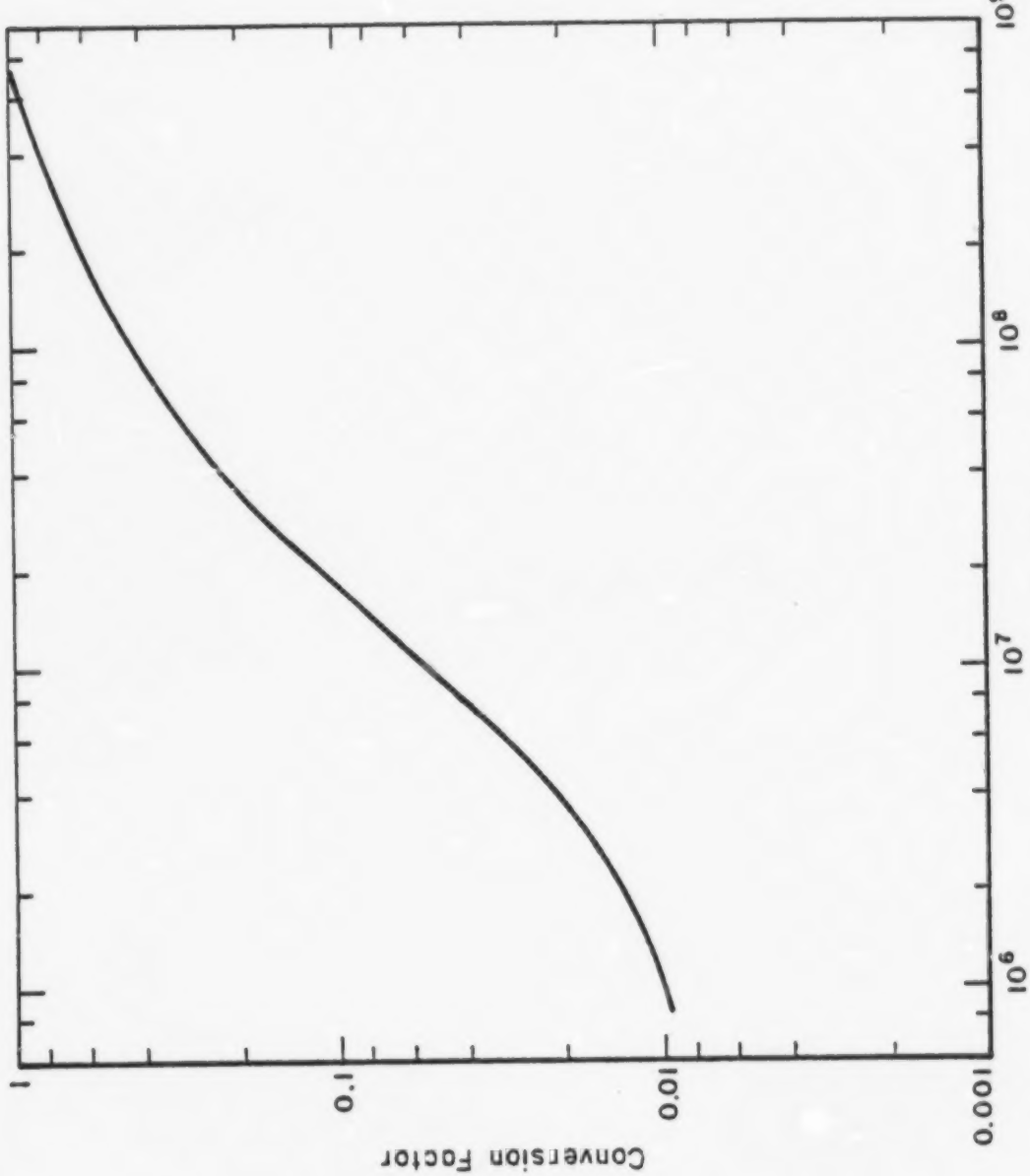

FIGURE 1. CONVERSION FACTOR TO DIVIDE INTO NEDS DATA TO OBTAIN TOTAL INSTALLED CAPACITIES IN EACH SIZE CLASS

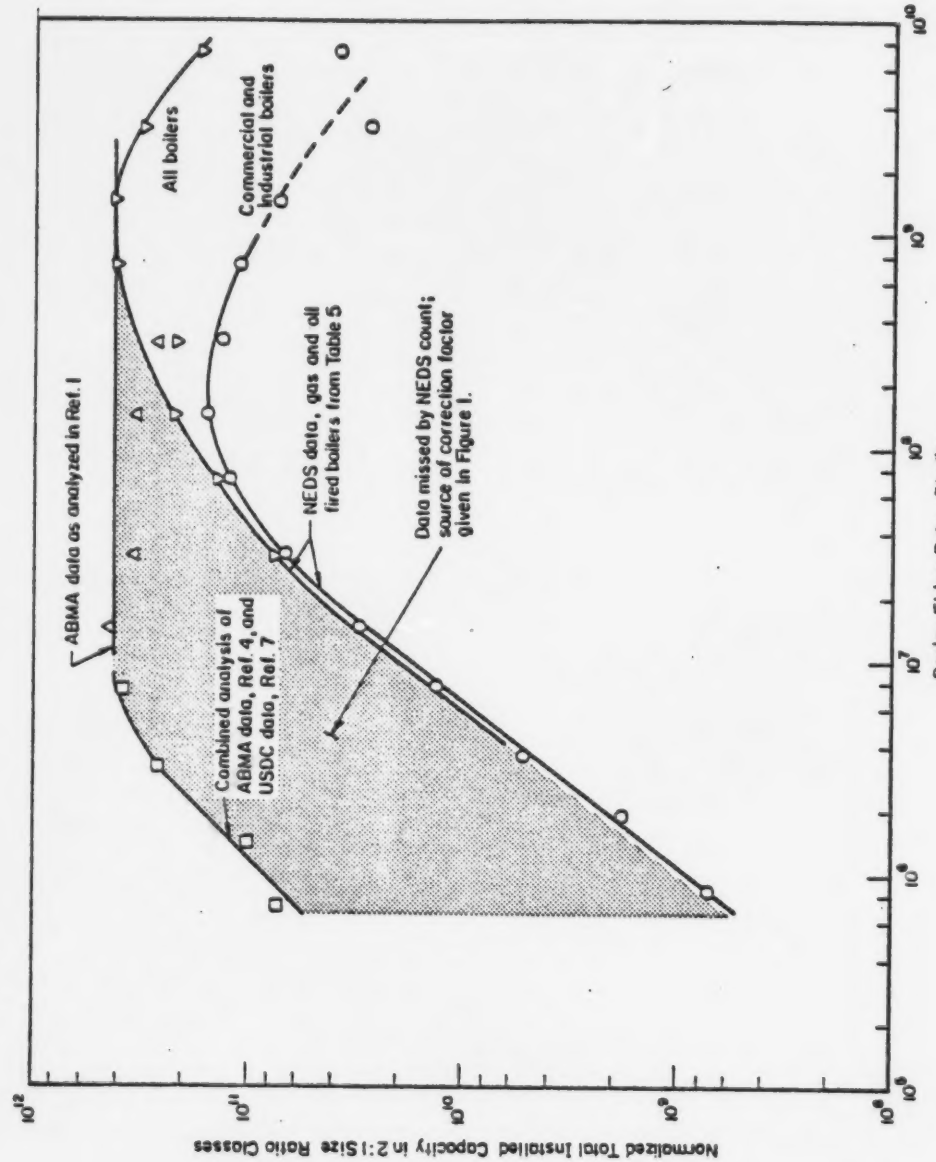
All boilers
Commercial and industrial boilers
ABMA data as analyzed in Ref. 1
Combined analysis of ABMA data, Ref 4, and USDC data, Ref. 7
NEDS data, gas and oil fired boilers from Table 5
Data missed by NEDS count; source of correction factor given in Figure 1.
Normalized Total Installed Capacity in 2:1 Size Ratio Classes
Design Firing Rate, Btu/hr

FIGURE 2. NORMALIZED TOTAL INSTALLED CAPACITIES IN 2:1 SIZE CLASSES AS A FUNCTION OF DESIGN SIZE

(3) The range of boilers with firing rates from 10^6 through 10^7 is handled in a manner similar to that of the next higher range, using ABMA and other data sources[6,7]. The procedure is outlined in Appendix B. It might be noted that in recent years hot air units have started to make important inroads for firing rates up to 5×10^6 Btu/hr, but no sales counts appear to be available for these units and they could not be included.

(4) Residential heating systems are treated separately (as reported in the next section).

Unfortunately, some utility boilers that are reported in Table 5 are not consistent with known boiler data. For example, the largest boilers ever built are about 1200 to 1500 megawatts, equivalent to about 12 to 15×10^9 Btu/hr fuel input. However, Table 7 lists 8 units above this size range. Obviously, these units do not exist. Unfortunately, the NEDS computer tapes that were used as the primary data source on utility boilers listed these "impossible" units. The scope of this task did not include correcting the NEDS data and, hence, they are tabulated in Tables 5 and 7. Although the "impossible" units were included in our number count of boilers, their reported capacities (up to 54,000 megawatts) were not included in our boiler capacity tables or figures. These boilers are omitted from calculations and listings in subsequent tables, but do not significantly affect results.

Unfortunately, it is not so easy to identify possible NEDS errors at the small-size end of the utility boiler population. Some small boilers exist at power stations to serve as steam sources for powering auxiliaries during station startup. Additionally, utilities may have reported data on boilers used for space-heating of office facilities when the NEDS data were being compiled. Thus, separating small utility boilers that are real from NEDS errors is beyond the scope of this task and impossible without a major effort. Again, the small capacity of the units will not affect the general results reported in this study.

Table 7 is a compilation of the number count and the total installed capacity in each range of sizes after all corrections have been made. Furthermore, the average hourly fuel consumption, based on the total installed capacity of each boiler group times annual load factors, are presented. THIS TABLE REPRESENTS OUR BEST ESTIMATE OF ACTUAL BOILER COUNT, INSTALLED FIRING CAPACITY, AND AVERAGE HOURLY FUEL CONSUMPTION OR ACTUAL BOILER USE OF U.S. BOILERS FOR COMMERCIAL, INDUSTRIAL, AND UTILITY APPLICATIONS. (Residential data are reported in the next section and graphic displays of boiler population are given in the following section.)

TABLE 7. NUMBER COUNT, TOTAL INSTALLED CAPACITY (10^6 BTU/HR) AND AVERAGE HOURLY FUEL CONSUMPTION (ANNUAL LOAD FACTOR TIMES TOTAL INSTALLED CAPACITY) (10^6 BTU/HR) AS A FUNCTION OF DESIGN FIRING RATE, FUEL TYPE, AND USE.

	Design Firing Rate, Btu/hr														
	Size 0: 5^+ -$10x10^5$			Size 1: 1^+ -$2x10^6$			Size 2: 2^+ -$5x10^6$			Size 3: 5^+ -$10x10^6$			Size 4: 1^+ -$2x10^7$		
	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.
Stoker coal	4,910	1,754	1	3,387	1,967	1	4,998	3,946	6	3,917	3,264	3	1,378	2,004	14
	4,910	1,754	1	6,774	3,934	2	20,166	17,473	26	32,699	25,789	17	21,441	32,411	244
	1,498	747	0	2,066	1,676	1	6,151	7,443	12	9,973	10,986	8	6,540	13,807	117
Pulverized coal	0	281	0	109	765	0	0	689	0	27	326	0	63	428	2
	0	281	0	218	1,536	0	0	2,568	0	190	2,584	0	908	6,931	28
	0	147	0	92	802	0	0	1,346	0	81	1,354	0	385	3,632	12
Residual oil	5,261	8,067	4	3,496	8,959	7	7,891	23,109	7	3,972	13,983	12	2,620	7,453	17
	5,261	8,067	4	6,992	17,918	14	30,437	92,313	32	32,345	111,806	82	40,564	114,311	282
	1,289	2,969	1	1,713	6,594	5	7,457	33,971	12	7,925	41,145	30	9,938	42,066	104
Distillate oil	19,992	14,169	2	13,547	15,733	4	11,461	16,789	14	3,047	4,758	5	856	1,764	5
	19,992	14,169	2	27,094	31,466	8	43,401	65,320	56	22,824	37,514	36	11,879	26,879	90
	4,118	4,676	0	5,581	10,384	1	8,941	21,556	8	4,702	12,380	5	2,447	8,870	12
By-product gas	0	421	0	0	874	0	0	877	0	0	245	0	0	84	0
	0	421	0	0	1,748	0	0	3,064	0	0	2,176	0	0	1,315	0
	0	265	0	0	1,101	0	0	1,933	0	0	1,371	0	0	828	0
Natural gas	11,644	15,853	1	7,866	17,590	2	6,137	27,118	9	2,992	12,976	11	981	6,493	33
	11,644	15,853	1	15,732	35,180	4	24,174	106,591	35	24,157	102,013	78	15,355	100,021	489
	3,703	8,212	0	5,003	18,223	2	7,687	55,214	17	7,682	52,843	37	4,883	51,811	232
Sum	41,807	40,545	8	28,405	45,888	14	30,487	72,528	36	13,955	35,582	31	5,898	18,226	71
	41,807	40,545	8	56,810	91,782	28	118,178	287,333	151	112,215	281,882	213	90,147	281,868	1,133
	10,608	17,016	1	14,455	38,780	9	30,236	121,463	49	30,363	120,079	80	24,193	121,014	477
Class sum		82,360			74,307			103,051			49,568			24,195	
		82,360			148,620			405,662			394,310			373,148	
		27,625			53,244			151,748			150,522			145,684	

TABLE 7. (Continued)

	Design Firing Rate, Btu/hr														
	Size 5: 2^{+} -5x10^{7}			Size 6: 5^{+} -10x10^{7}			Size 7: 1^{+} -2x10^{8}			Size 8: 2^{+} -5x10^{8}			Size 9: 5^{+} -10x10^{8}		
	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.
Stoker coal	1,053	2,579	39	336	1,573	67	47	643	117	13	157	58	0	15	5
	35,447	91,937	1,482	24,609	115,979	5,546	6,088	92,010	17,701	3,831	45,085	16,503	0	11,071	3,005
	10,811	39,165	710	7,506	49,194	2,657	1,857	39,196	829	1,168	19,206	7,905	0	2,967	1,439
Pulverized coal	100	368	14	33	294	19	16	409	81	0	220	302	0	51	235
	3,289	14,100	592	2,518	24,679	1,549	2,229	60,155	12,517	0	66,569	103,283	0	33,022	168,744
	1,395	7,388	250	1,068	12,932	655	945	31,521	5,295	0	34,882	43,688	0	19,152	71,379
Residual oil	1,926	5,058	17	621	1,785	82	151	743	168	41	285	243	4	44	163
	65,042	169,137	282	44,009	131,806	5,497	20,914	106,429	25,930	13,009	86,684	74,605	4,209	30,273	111,307
	1,593	62,242	104	10,782	48,505	2,023	5,124	39,166	9,542	3,187	31,900	27,455	1,031	11,140	57,165
Distillate oil	442	858	5	121	203	14	41	114	43	17	29	67	3	3	33
	13,558	28,063	90	8,879	15,992	1,070	6,149	16,388	6,239	5,833	8,717	20,949	1,907	2,492	21,735
	2,793	9,261	12	1,829	5,264	139	1,267	5,408	811	1,202	2,877	2,723	393	822	2,826
By-product gas	0	174	0	0	170	0	0	137	0	0	60	4	0	26	0
	0	7,058	0	0	12,124	0	0	18,108	0	0	19,181	1,496	0	16,554	0
	0	4,447	0	0	7,638	0	0	11,408	0	0	12,089	942	0	10,429	0
Natural gas	684	5,000	56	224	2,158	43	100	918	181	36	324	33	5	75	241
	21,721	276,642	1,950	17,691	156,194	6,161	13,982	136,580	27,733	12,099	98,373	108,281	2,794	48,744	169,221
	6,967	149,404	924	5,626	80,908	2,920	4,319	70,798	13,145	3,835	50,957	51,325	888	25,249	80,210
Sum	4,205	14,037	131	1,335	6,183	265	355	2,964	590	107	1,075	707	12	214	677
	139,057	587,137	4,396	98,706	456,774	19,823	49,362	429,670	90,118	34,772	324,609	325,118	8,910	142,161	474,012
	23,559	271,907	2,000	26,811	204,441	8,394	13,512	197,497	29,622	9,392	151,911	134,038	2,312	69,759	213,019
Class sum		18,373			7,783			3,909			1,889			903	
		730,590			575,303			569,150			684,499			625,083	
		297,466			239,646			240,631			295,341			285,090	

TABLE 7. (Continued)

	Design Firing Rate, Btu/hr														
	Size 10: 1^{+}-2×10^{9}			Size 11: 2^{+}-5×10^{9}			Size 12: 5^{+}-10×10^{9}			Size 13: 1^{+}-2×10^{10}			Size 14: > 2×10^{10}		
	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.	Com.	Ind.	Ut.
Stoker coal	0	5	2	0	2	2	0	0	0	0	0	0	0	0	0
	0	6,851	3,123	0	7,600	6,132	0	0	0	0	0	0	0	0	0
	0	1,836	1,496	0	2,037	2,937	0	0	0	0	0	0	0	0	0
Pulverized coal	0	10	266	0	5	125	0	1	53	0	0	2	0	0	4
	0	16,019	370,857	0	11,995	378,536	0	5,068	327,022	0	0	22,466	0	0	-
	0	9,291	159,410	0	6,928	160,121	0	2,939	138,330	0	0	9,503	0	0	-
Residual oil	0	12	83	0	1	43	0	0	5	0	0	0	0	0	0
	0	17,450	114,113	0	3,020	128,886	0	0	26,906	0	0	0	0	0	0
	0	6,422	57,910	0	1,111	70,068	0	0	17,408	0	0	0	0	0	0
Distillate oil	0	0	3	0	1	1	0	0	1	0	0	1	0	0	0
	0	0	4,129	0	2,274	2,854	0	0	5,184	0	0	13,070	0	0	0
	0	0	537	0	750	371	0	0	674	0	0	1,699	0	0	0
By-product gas	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	5,604	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	3,531	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural gas	4	32	174	1	11	80	0	5	17	1	4	1	1	2	1
	6,301	46,063	242,621	2,626	28,908	247,992	0	38,964	101,915	10,350	61,550	10,981	-	-	-
	2,004	23,861	115,010	835	14,474	117,548	0	20,183	48,308	3,291	31,883	5,191	-	-	-
Sum	4	63	528	1	20	251	0	6	76	1	4	4	1	2	5
	6,301	91,987	734,837	2,626	53,797	764,400	0	44,032	461,027	10,350	61,550	46,517	-	-	-
	2,004	44,941	354,404	835	25,300	351,045	0	23,122	204,720	3,291	31,883	16,393	-	-	-
Class sum		595			272			82			9			8	
		833,125			820,823			505,059			118,417			-	
		401,349			377,180			227,842			51,567			-	

RESIDENTIAL HEATING SYSTEMS

The residential sector includes dwelling units of all types. The majority of dwelling units in the United States are single family houses, but the sector also includes mobile homes; duplex, triplex, and quadruplex units; and apartment buildings of five or more dwelling units. Vacation homes are not year-round residences and are not included.

The number of residential heating systems by type in April, 1970, as determined by the Bureau of Census, is given in Table 8. In the Census data, the size of unit was not included, and the fuel type was tabulated separately. For the purpose of estimating and controlling emissions from residential heating systems, the type of fuel is of greater significance than the type of heating unit. Although there are some differences in emissions among different types of heating units, these are generally small compared to the differences among fuels. Hence, they were neglected.

The estimated number of residential dwelling units by fuel is summarized in Table 9. In the multiple dwelling units, some have individual heating systems and some utilize a central heating system. It is expected that while most electrical heating systems in apartment houses are individual, most apartment gas- and petroleum-fueled systems are supplied from a central boiler.

No specific data on the size of residential heating systems were found during this study. Some inferences can be made from the estimates of Table 10. Better estimates of size could be made by considering both the type of dwelling and the geographic location. That level of detail could be obtained in a more intensive study but was beyond the scope of the present investigation.

Estimated fuel consumption for space heating by residential units is summarized in Table 11. These estimates were based upon data from the Bureau of Mines[10] and the Stanford Research Institute[11]. The national average fuel consumption per dwelling unit is also summarized in Table 11.

TABLE 8. RESIDENTIAL DWELLING UNIT HEATING PLANTS[a] (12)

In Thousands of Heating Units

	All Units	Occupied Units
Steam or hot water	13,820	13,211
Warm air furnace	28,772	27,515
Built in electric	3,520	3,236
Floor, wall, or pipeless furnace	5,878	5,552
Room heaters with flue	7,910	7,209
Room heaters without flue	3,949	3,558
Fireplaces, stoves, or portable heaters	3,269	2,766
None	581	398
Total	67,699	63,445

(a) Includes all year-round living quarters--single family houses, apartments and mobile homes.

TABLE 9. ESTIMATED NUMBER OF DWELLING UNITS HEATED BY VARIOUS FUELS

In Millions of Dwelling Units

	April, 1970	End, 1971	December, 1974
Natural gas	35.0	36.7	39.4
Oil	16.5	15.8	14.8
Electricity	4.9	5.7	8.8
Bottled or LP gas	3.8		
Coal or coke	1.8	6.6	6.5
Wood	0.8		
Other	0.2		
No heat	0.4	0.4	0.4
Total	63.4	65.2	69.9

TABLE 10. ESTIMATED NUMBER OF DWELLING UNITS, BY TYPE, HEATED BY VARIOUS FUELS IN DECEMBER, 1974

In Thousands of Dwelling Units.

Fuel	Single Family Dwelling	Mobile Home	2-4 Units	5+ Units	All Units
Natural gas	27,400	925	5,625	5,475	39,425
Oil	9,350	1,300	1,750	2,400	14,800
Electricity	5,000	450	625	2,700	8,775
Other[a]	4,950	850	450	675	6,925
Total	46,700	3,525	8,450	11,250	69,925

(a) Other is about 75 percent LP gas.

TABLE 11. ESTIMATED 1971 FUEL CONSUMPTION FOR RESIDENTIAL SPACE HEATING

	Fuel Consumed, 10^{12} Btu	Fuel Consumed Per Dwelling Unit, 10^{6} Btu
Natural gas	3,695	100
LP and bottle gas	530	139
Kerosine	380	153
Distillate fuel oil	2044	
Residual fuel oil[a]	negligible	--
Coal[a]	negligible	--

(a) There was probably a small amount of residual fuel oil and coal consumed in central heating systems of apartment buildings, but this is believed to be negligible based on Reference 11.

The available population data on residential heating systems is not in a form compatible with the majority of the boiler analysis. To put it in a compatible form, some assumptions have to be made that are believed sufficiently accurate to complete the distribution picture. However it is obvious that size distributions of the small heating units would be required to produce more reliable results.

To carry out the analysis, arbitrary distributions were made in multiple family units between those having a single furnace per family unit, and those having one furnace or boiler per complex. As a result the number of heating units becomes less than the number of family units.

To estimate fuel consumption, an arbitrary, but reasonable, design firing rate was assigned to the heating units in each class, and the Walden[9] annual load factor of 20 percent as an average for residential units was applied to the data. The total consumption agreed with the values given in Tables 10 and 11.

Tables 12 and 13 resulted from these assumptions. Further refinement was not justified considering the data that are available. Table 13 (residential data) is used to complement Table 7 (which contains data on commercial, industrial, and utility boilers).

From the viewpoint of reducing emissions, the above data can provide only general guidance. When combines with information presented elsewhere in this report, it gives perspective on the relative magnitude of emissions from residential heating systems as compared with utility, industrial, and commercial boilers. If, in the judgment of EPA, residential heating is a problem worthy of further investigation, a regional approach is suggested. The requirements for residential heating are greatest in the northern states, and the use of petroleum is greatest in the northeast.

Combustion of petroleum fuels emits more atmospheric pollutants than other residential heating methods. (The use of coal in residential heating is negligible.) In addition, because heating is seasonal and the health hazards of atmospheric emissions appear to depend upon relatively short-term levels (hours to days), the use of heating systems in winter would have greater meaning than the national year-round average. A more meaningful study would consider the consumption of fuels in the winter months in the northeast and possibly in other selected northern locations.

TABLE 12. DISTRIBUTION OF NUMBER OF UNITS (UPPER VALUE) AND DESIGN FIRING RATE OF INDIVIDUAL UNITS (LOWER VALUE) TO MATCH DATA IN TABLES 10 and 11 AND ASSUMPTION OF 20 PERCENT ANNUAL LOAD FACTOR

		Single Family Furnace		Multiple Family Furnace		
	Mobile Homes	Small Units	Large Units	Small Units	Intermediate Units	Large Units
LPG	637,500	3,704,250	852,000	0	0	0
	50,000	50,000	100,000	0	0	0
Natural Gas	925,000	32,336,000	2,064,000	350,000	225,000	150,000
	40,000	50,000	100,000	240,000	360,000	540,000
Oil	1,300,000	4,880,000	5,940,000	220,000	150,000	100,000
	50,000	80,000	120,000	320,000	480,000	720,000

TABLE 13. NUMBER COUNT, TOTAL INSTALLED CAPACITY (10^6 BTU/HR), AND AVERAGE HOURLY FUEL CONSUMPTION (ANNUAL LOAD FACTOR TIMES TOTAL DESIGN FIRING CAPACITY) (10^6 BTU/HR) AS A FUNCTION OF DESIGN FIRING RATE AND FUEL TYPE FOR RESIDENTIAL BOILERS

	Boiler Design Firing Rates, Btu/hr				
	2^+-$5x10^4$	5^+-$10x10^4$	1^+-$2x10^5$	2^+-$5x10^5$	5^+-$10x10^5$
Distillate oil and kerosine		6,180,000	5,940,000	370,000	100,000
		455,400	712,800	142,400	72,000
		91,080	142,560	28,480	14,400
Natural Gas	925,000	32,336,000	2,064,000	575,000	150,000
	37,000	1,616,800	206,400	165,000	81,000
	7,400	323,360	41,280	33,000	16,200
LPG		4,341,750	852,000		
		217,088	85,200		
		43,418	17,040		
TOTAL	925,000	42,857,950	8,856,000	945,000	250,000
	37,000	2,289,288	1,004,400	307,400	153,000
	7,400	457,858	200,880	61,480	30,600
Normalizing Ratio	1.322	1.000	1.000	1.322	1.000

GRAPHICAL SUMMARY OF BOILER POPULATION DATA

This section of the report contains several figures that graphically portray the summary data on boiler population presented in Tables 7 and 13.

Figure 3 presents the total installed capacity distribution for 2:1 firing rate increments. Some increments tabulated in Table 7 cover a 2.5:1 firing rate increment; data for these increments were normalized to a 2:1 design firing rate increment before plotting on Figure 3. Figure 3 is intended to show graphically total installed capacity versus design firing rate by small increments for all boilers. Similar plots can be made for individual fuel and/or use, and for average hourly fuel consumption or actual boiler use (design firing rate times the annual load factor). The total installed capacity and actual boiler use show a peak in the residential area, a low value at a design firing rate of about 10^6 Btu/hr, climb smoothly to a peak at a design firing rate of about 10^9 Btu/hr, and then drop rapidly. Instinctively, it is felt that both peaks may be too sharp. It is known that data on commercial warm air heaters are missing in the low part of the curve; though the missing data would not eliminate this low region, it would make it considerably less pronounced.

Figure 4 shows the distribution of design firing capacity based on type of boiler use, compiled from Table 7. Because of the small number of boilers at the high design firing rates, large fluctuations result and the data are not shown. As expected, it is clear that the typical boiler use changes with design firing rate. As boiler size increases, the application of most boilers within a given size increment shifts from residential to commercial, to industrial, and to utility for the largest size boilers.

Figure 5 presents the cumulative installed boiler capacity for all boilers included in this study. Separate curves are shown for coal-fired, oil-fired, and gas-fired boilers and for boilers fired by all

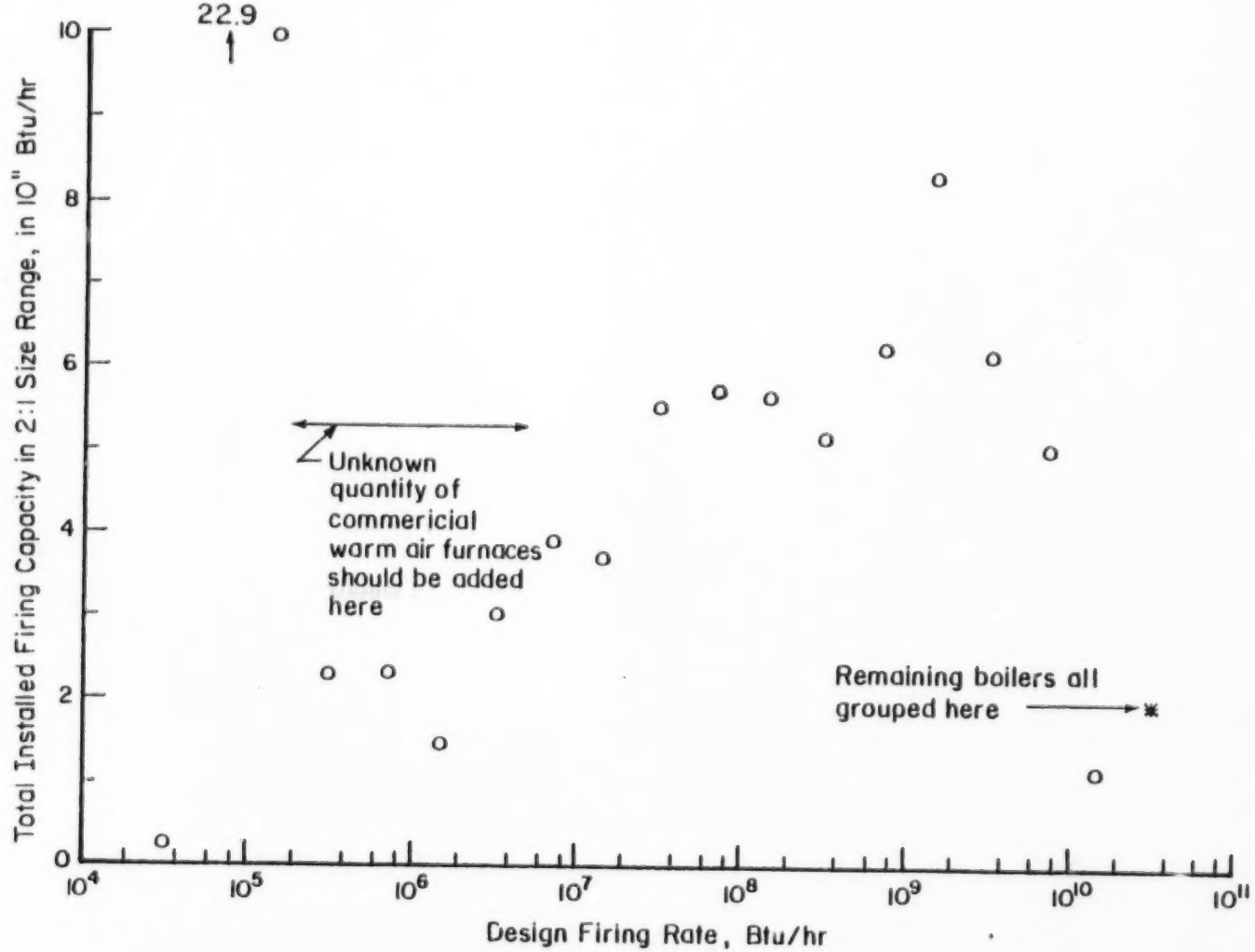
22.9
Total Installed Firing Capacity in 2:1 Size Range, in 10" Btu/hr
Unknown quantity of commericial warm air furnaces should be added here
Remaining boilers all grouped here
Design Firing Rate, Btu/hr

FIGURE 3. TOTAL INSTALLED CAPACITY IN EACH BOILER SIZE INCREMENT

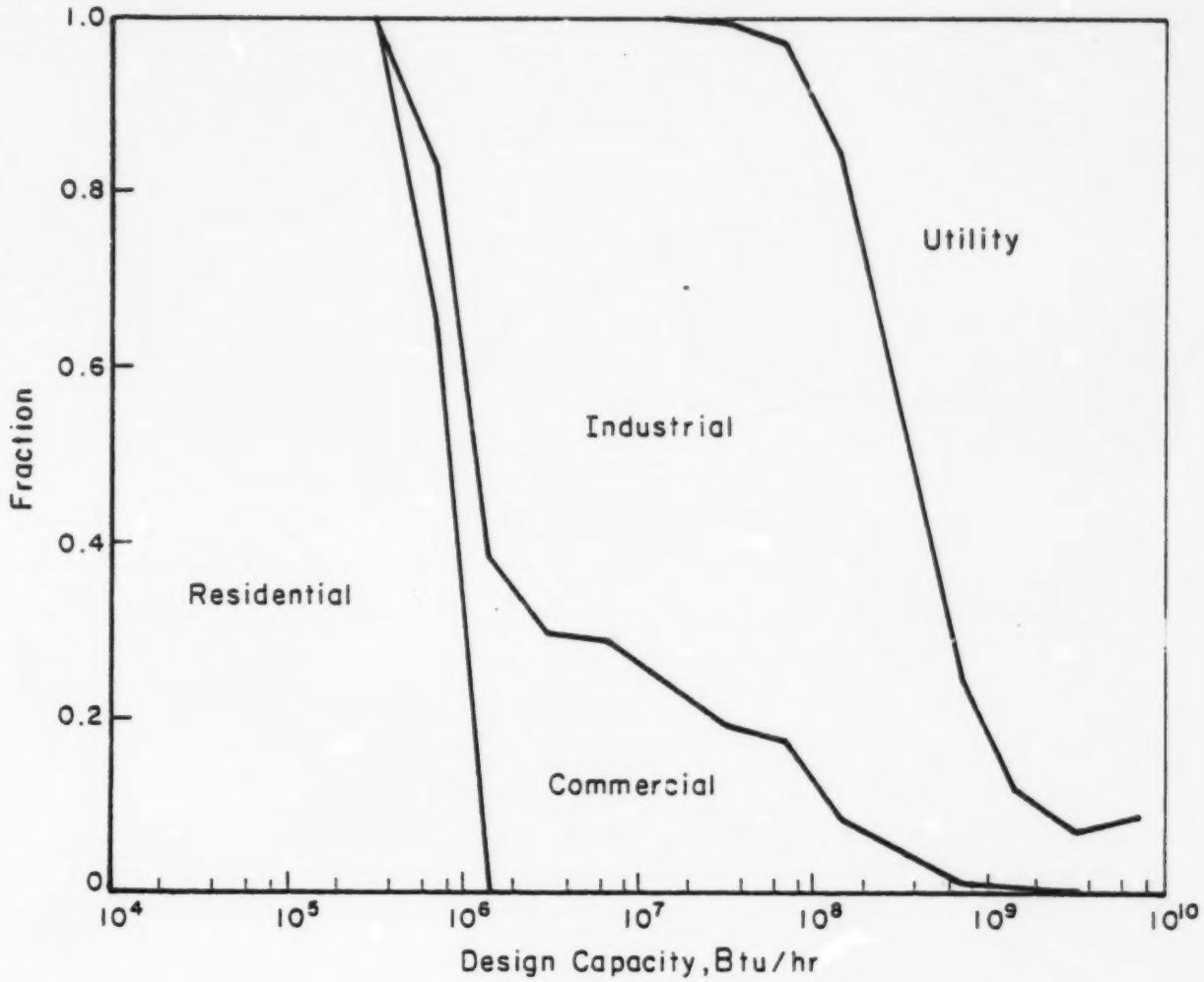

FIGURE 4. BOILER USE RELATED TO BOILER SIZE

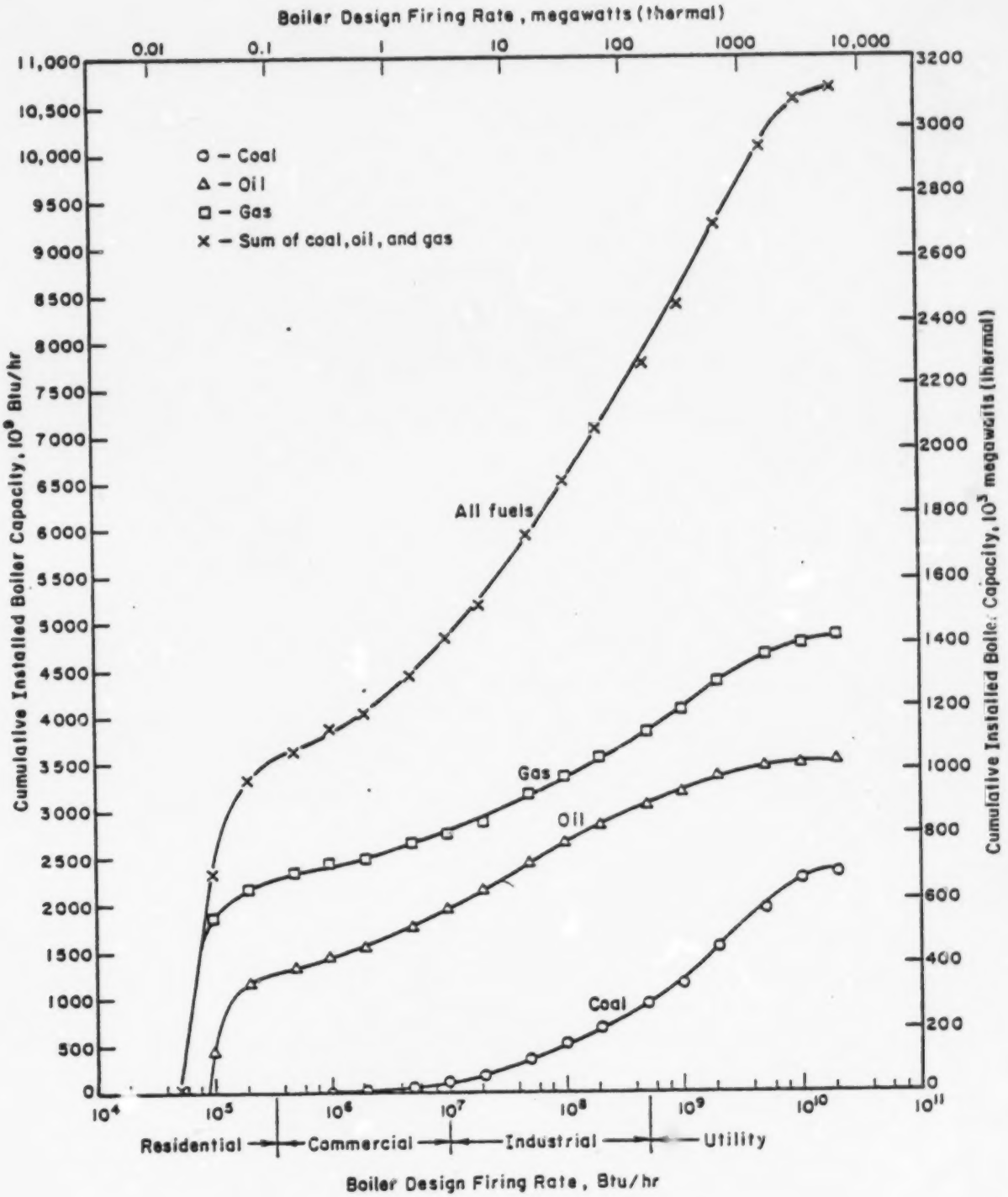

FIGURE 5. CUMULATIVE INSTALLED BOILER CAPACITY FOR COAL, OIL, AND GAS-FIRED BOILERS

fuels. The size ranges generally used to define boiler use are shown across the bottom of the figure. (Early discussions showed that these definitions are not adequate for defining actual boiler use as there is considerable overlap in the use of many sizes of boilers.)

Examination of Figure 5 shows that gas- and oil-fired boilers with firing rates below 10^6 Btu/hr make up 36 percent of the total installed boilers capacity in the United States. Gas- and oil-fired boilers continue to account for a sizeable portion of boiler capacity, even for the larger sizes of boilers.

Figure 6 presents the cumulative actual boiler use (or average hourly fuel consumption) for all boilers included in this study.

In examining Figure 6, it is found that gas- and oil-fired boilers with firing rates below 10^6 Btu/hr contribute 21.6 percent of actual boiler use (versus 36 percent of installed boiler capacity). From Figure 6 it is seen that the curve for actual boiler use (all fuels) approaches a straight-line (with a hump at about 2×10^5 Btu/hr and a dip at about 3×10^6 Btu/hr). The interpretation of this is that, from the viewpoint of total fuel use, nearly all sizes of boilers consume nearly equal quantities of fuel. Hence, small boilers have as significant an impact as large boilers. Of course, there is a shift of fuels with the size of boilers. The smaller units nearly all fire gas and oil; coal does not become a significant factor until boiler design firing rates exceed 10^7 Btu/hr.

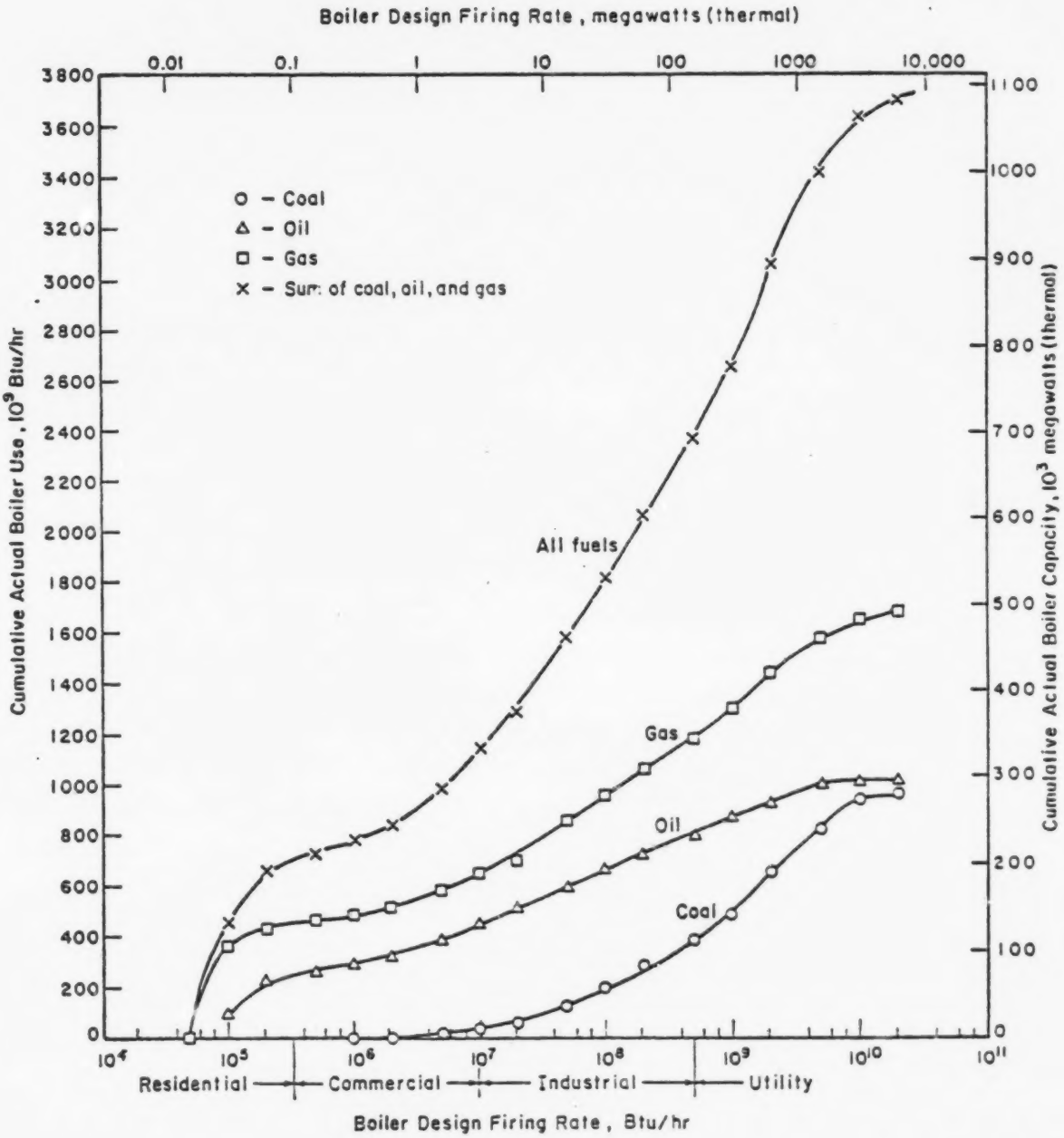

FIGURE 6. CUMULATIVE ACTUAL BOILER USE (OR AVERAGE HOURLY FIRING RATE) FOR COAL, OIL, AND GAS-FIRED BOILERS

ESTIMATED EMISSIONS OF SO_2, NO_x, AND PARTICULATE

Tables 14, 15, and 16 are estimates of SO_2, NO_x, and particulate emissions, respectively, for the total national boiler inventory of commercial, industrial, and utility boilers. Tables 17, 18, and 19 are estimates of SO_2, NO_x, and particulate emissions from residential units. These estimates were made using published EPA emission factors[13] and other recent emission data[14,15], except for by-product gas fuels. Two numbers are given for each boiler size and category. The top number is an estimate of potential annual emissions based on the total installed capacity of a given class of boilers. The second number is an estimate of annual emissions based on annual fuel consumption or actual boiler use (total installed capacity adjusted by the annual load factor) for the respective class.

In the case of by-product gas, SO_2 emissions were based on the sulfur content of typical coke-oven gas. Precise estimates of NO_x or particulate emissions were not possible since emissions vary with fuel composition and the actual fuel composition was unknown. Therefore, EPA emission factors for natural gas combustion in industrial boilers[13] were used to estimate NO_x and particulate emissions from boilers fired with gaseous fuels other than natural gas or LPG.

Figures 7, 8, and 9 show cumulative emissions of SO_2, NO_x, and particulate, respectively, for all boilers based on actual boiler use. On each figure, where pertinent, separate curves are shown for gas-fired, oil-fired, and coal-fired boilers and for the sum for all fuels. Interesting observations from these figures include:

Figure 7 - About 11 percent of SO_2 emissions are from boilers with firing rates below 10^7 Btu/hr (the nominal "residential" and "commercial" boilers)

- About 59 percent of SO_2 and emissions are from boilers with firing rates over 5×10^8 Btu/hr (the nominal "utility" boilers)

- Oil-fired boilers contribute greater SO_2 emissions than do coal-fired boilers for small boilers. For each firing rate size increment above about 10^7 Btu/hr, coal-fired boilers contribute greater SO_2 emissions than do oil-fired boilers

Figure 8 - About 23 percent of NO_x emissions are from boilers with firing rates below 10^7 Btu/hr (the nominal "residential" and "commercial" boilers)

- About 50 percent of NO_x emissions are from boilers with firing rates over 5×10^8 Btu/hr (the nominal "utility" boilers)

- Except for small coal-fired units (where the number of units is small), boilers firing all fuels contribute significantly to NO_x emissions over nearly the entire range of firing rates

Figure 9 - About 3.0 percent of particulate emissions are from boilers with firing rates below 10^7 Btu/hr

- Coal-fired boilers account for nearly all particulate emissions.

TABLE 14. SULFUR DIOXIDE EMISSIONS (TONS/YR) BY BOILER SIZE CLASS [a]

Top Number is Potential Emissions (Based on Installed Boiler Capacity); Lower Number is Actual Emissions (Based on Annual Fuel Consumption Or Actual Boiler Use)

Fuel	Size 0: 5^{+}-10 x 10^{5} Btu/hr			Size 1: 1^{+}-2 x 10^{6} Btu/hr			Size 2: 2^{+}- 5 x 10^{6} Btu/hr			Size 3: 5^{+}-10 x 10^{6} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal, Low Sulfur	13,993.0 4,269.3	5,027.5 2,509.3	0 0	19,305.3 5,887.9	8,143.8 4,065.8	0 0	55,398.3 16,897.5	57,938. 24,681.8	0 0	186,993.2 57,032.1	74,815.7 31,871.2	0 0
Stoker Coal, High Sulfur	40,155.0 12,250.0	3,497.2 1,489.1	15.6 0	55,398.0 16,896.1	12,746.1 5,430.2	31.3 15.6	169,298.4 51,638.9	501,124.2 213,466.7	1,941.9 896.2	154,839.3 47,224.6	313,632.4 133,605.8	0 0
Pulverized Coal, Low Sulfur	0 0	944.8 494.3	0 0	821.2 346.5	5,164.4 2,696.5	0 0	0 0	8,578.6 4,496.2	0 0	735.0 313.4	11,718.2 6,140.3	0 0
Pulverized Coal, High Sulfur	0 0	3,118.0 1,087.4	0 0	0 0	17,043.5 8,899.0	0 0	0 0	27,816.6 14,580.8	0 0	0 0	0 0	0 0
Residual Oil, Low Sulfur	12,299.0 2,394.8	27,378.0 10,080.0	0 0	16,345.4 3,182.6	60,836.2 22,388.1	40.9 14.7	92,259.0 22,603.5	354,549.5 130,473.5	211.4 79.2	63,543.9 15,569.0	302,675.7 111,135.7	544.5 199.3
Residual Oil, High Sulfur	39,770.0 9,744.3	78,760.0 28,987.0	39.2 9.9	52,855.4 12,949.5	174,938.2 64,379.7	19.6 6.9	85,125.3 2,055.4	1,050,932.6 386,741.1	52.4 19.8	1,074,148.4 263,184.3	1,245,368.0 458,300.0	165.5 60.4
Distillate Oil, Low Sulfur	39,001.0 5,355.6	17,713.0 5,845.5	0.9 0	35,237.4 7,258.4	39,336.0 12,981.2	3.4 .4	49,072.0 9,834.9	60,079.7 12,377.0	34.0 4.9	33,491.2 6,899.6	92,901.1 30,658.3	15.7 2.2
Distillate Oil, High Sulfur	12,555.3 2,586.3	4,301.3 1,419.6	0 0	17,015.5 3,504.9	9,552.4 3,152.6	0 0	26,593.3 5,478.3	24,484.6 5,044.3	0 0	12,684.5 2,613.4	31,656.6 10,447.0	0 0
By-product Gas, Low Sulfur	0 0	9.8 6.1	0 0	0 0	40.5 25.5	0 0	0 0	71.0 44.8	0 0	0 0	41.8 26.4	0 0
By-product Gas, High Sulfur	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	214.3 135.0	0 0
Natural Gas, Low Sulfur	30.6 9.7	40.9 21.6	0 0	41.4 13.2	92.5 47.9	0 0	63.6 20.2	280.3 145.2	0 0	63.5 20.7	268.3 139.0	0 0
Natural Gas, High Sulfur	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0

(a) Average sulfur content of fuels fired in each class of boilers obtained from NEDS data (Reference 2).

TABLE 14. (Continued)

Fuel	Size 4: 1^{+}-2 x 10^{7} Btu/hr			Size 5: 2^{+}-5 x 10^{7} Btu/hr			Size 6: 5^{+}-10 x 10^{7} Btu/hr			Size 7: 1^{+}-2 x 10^{8} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal,	49,113.2	101,075.7	8,488.7	87,819.6	187,626.8	3,601.2	66,312.8	249,368.1	25,293.8	6,334.6	254,713.7	60,636.2
Low Sulfur	14,980.6	43,058.3	4,074.9	26,784.0	79,928.7	759.1	19,920.6	105,772.9	12,118.1	1,932.1	108,507.3	2,839.5
Stoker Coal,	206,802.6	561,292.9	1,980.1	330,131.8	1,429,050.3	24,912.2	257,673.4	1,502,051.4	52,515.3	94,402.6	1,092,888.4	170,690.9
High Sulfur	64,869.7	238,886.4	948.8	100,687.8	608,772.8	11,934.8	78,593.9	637,114.0	25,158.5	28,795.5	465,567.5	7,994.5
Pulverized Coal,	0	36,825.1	9.3	14,272.5	27,462.6	1,459.4	3,816.2	37,197.8	1,724.4	7,356.2	130,612.4	11,133.0
Low Sulfur	0	19,297.3	40.0	6,053.5	14,389.6	616.0	1,618.5	19,869.5	729.5	3,118.9	68,440.7	4,709.9
Pulverized Coal,	5,727.	32,045.2	222.3	22,297.2	179,053.5	1,993.6	11,362.4	314,961.7	42,726.6	10,351.7	699,090.0	264,865.6
High Sulfur	2,428.3	16,791.9	95.3	9,457.4	93,818.9	841.8	4,823.3	165,041.7	18,068.6	4,472.9	366,320.	117,045.8
Residual Oil,	79,171.9	295,755.5	455.7	107,708.6	333,207.6	290.9	78,357.5	321,849.8	7,562.3	44,111.5	244,067.9	64,851.2
Low Sulfur	19,396.6	108,100.6	168.9	2,637.9	122,619.7	107.3	19,197.2	11,844.2	2,783.1	10,880.9	89,897.2	23,864.6
Residual Oil,	316,506.0	839,968.0	3,320.4	414,158.7	1,300,827.	1,949.6	288,704.7	1,099,533.	39,487.3	116,918.4	739,378.5	130,721.8
High Sulfur	77,542.9	309,105.	1,225.1	10,143.8	478,701.8	719.0	70,731.1	404,632.	14,532.4	28,646.5	272,092.4	48,104.4
Distillate Oil,	9,435.5	38,537.8	83.2	11,580.6	26,111.3	0	9,110.2	33,281.4	1,438.7	10,141.2	75,331.1	7,774.1
Low Sulfur	1,943.6	12,717.4	11.1	2,385.7	8,616.9	0	1,876.7	10,955.	186.9	2,089.6	24,859.1	1,010.5
Distillate Oil,	15,086.6	8,811.6	0	11,001.8	48,802.5	0	3,499.1	32,331.1	4,304.5	2,017.2	6,358.5	0
High Sulfur	3,107.8	2,907.6	0	2,266.2	16,105.4	0	720.6	10,642.3	558.2	415.6	2,098.3	0
By-product Gas,	0	30.5	0	0	106.3	0	0	212.8	0	0	314.6	0
Low Sulfur	0	19.2	0	0	67.0	0	0	134.1	0	0	198.2	0
By-product Gas,	0	0	0	0	572.3	0	0	681.0	0	0	1,048.0	0
High Sulfur	0	0	0	0	360.6	0	0	429.0	0	0	660.7	0
Natural Gas,	40.4	263.	1.3	57.1	728.	5.2	46.5	410.8	16.2	36.8	359.	72.9
Low Sulfur	12.8	1,226.3	6.1	18.3	392.9	2.4	14.8	212.8	7.7	11.4	186.	34.6
Natural Gas,	0	0	0	0	0	0	0	0	0	0	0	0
High Sulfur	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 14. (Continued)

Fuel	Size 8: 2^{+}-5 x 10^{8} Btu/hr			Size 9: 5^{+}-10 x 10^{8} Btu/hr			Size 10: 1^{+}-2 x 10^{9} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal,	6,927.6	86,723.6	3,199.8	0	6,169.6	1,892.3	0	27,157.6	0
Low Sulfur	2,111.9	36,943.9	1,532.7	0	1,653.5	5,694.9	0	7,277.9	0
Stoker Coal,	59,889.0	227,296.1	268,163.2	0	471,614.2	41,765.2	0	46,209.7	158,391.8
High Sulfur	18,260.1	96,877.0	128,451.0	0	126,393.5	20,000.1	0	12,383.4	75,873.9
Pulverized Coal,	0	99,358.1	99,744.3	0	41,274.4	233,517.5	0	27,751.7	493,300.2
Low Sulfur	0	52,063.5	42,191.4	0	23,938.1	98,778.0	0	16,096.0	212,041.2
Pulverized Coal,	0	716,952.4	2,896,232.3	0	1,568,542.4	4,439,993.3	0	253,371.6	9,026,003.0
High Sulfur	0	375,681.0	1,225,072.4	0	909,683.0	1,878,124.8	0	146,954.9	3,879,758.0
Residual Oil,	23,647.4	71,458.5	194,919.3	25,157.2	57,840.4	346,274.4	0	15,705.8	205,602.5
Low Sulfur	5,793.0	26,297.0	71,731.2	6,162.3	21,284.4	177,839.5	0	5,780.0	104,339.0
Residual Oil,	36,086.9	756,032.4	494,003.2	0	203,247.9	471,242.3	0	90,857.1	234,660.3
High Sulfur	8,841.0	278,222.2	181,797.6	0	74,792.0	242,020.2	0	33,438.0	119,085.3
Distillate Oil,	5,681.0	5,621.2	22,203.6	1,689.8	1,709.2	21,967.0	0	0	17,016.4
Low Sulfur	1,170.7	1,855.3	2,886.1	348.2	563.8	2,856.1	0	0	2,213.1
Distillate Oil,	0	0	0	0	0	0	0	0	0
High Sulfur	0	0	0	0	0	0	0	0	0
By-product Gas,	0	412.6	0	0	0	0	0	0	0
Low Sulfur	0	260.1	0	0	0	0	00	0	0
By-product Gas,	0	1,110.9	693.2	0	3,835.1	0	0	1,298.3	0
High Sulfur	0	700.2	436.5	0	2,416.1	0	0	818.0	0
Natural Gas,	71.8	258.7	284.8	7.3	128.0	445.0	16.6	121.1	638.0
Low Sulfur	10.0	134.0	135.0	2.3	66.4	211.0	5.3	62.7	302.5
Natural Gas,	0	0	0	0	0	0	0	0	0
High Sulfur	0	0	0	0	0	0	0	0	0

TABLE 14. (Continued)

Fuel	Size 11: 2^{+}-5 x 10^{9} Btu/hr			Size 12: 5^{+} -10x10^{9} Btu/hr			Size 13: 1^{+} -2x10^{10} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal,	0	0	0	0	0	0	0	0	0
Low Sulfur	0	0	0	0	0	0	0	0	0
Stoker Coal,	0	177,243.8	157,332.4	0	0	0	0	0	0
High Sulfur	0	47,506.0	75,356.4	0	0	0	0	0	0
Pulverized Coal,	0	0	1,019,488.0	0	0	593,083.0	0	0	0
Low Sulfur	0	0	43,124.5	0	0	250,874.0	0	0	0
Pulverized Coal,	0	84,826.2	9,839,853.0	0	232,136.0	6,370.437.0	0	0	765,264.0
High Sulfur	0	48,993.4	4,162,264.0	0	134,613.0	2,694,689.0	0	0	323,703.0
Residual Oil,	0	0	407,225.9	0	0	0	0	0	0
Low Sulfur	0	0	221,385.3	0	0	0 0	0	0	0
Residual Oil,	0	0	716,123.3	0	0	306,257.5	0	0	0
High Sulfur	0	0	389,316.1	0	0	198,146.6	0	0	0
Distillate Oil,	0	0	4,539.0	0	0	16,124.9	0	0	22,804.9
Low Sulfur	0	0	590.0	0	0	2,096.5	0	0	2,964.5
Distillate Oil,	0	0	0	0	0	0	0	0	0
High Sulfur	0	0	0	0	0	0	0	0	0
By-product Gas,	0	0	0	0	0	0	0	0	0
Low Sulfur	0	0	0	0	0	0	0	0	0
By-product Gas,	0	0	0	0	0	0	0	0	0
High Sulfur	0	0	0	0	0	0	0	0	0
Natural Gas,	6.9	76.0	652.2	0	102.5	268.0	27.2	161.9	28.9
Low Sulfur	2.2	38.0	309.1	0	53.1	127.0	8.7	83.8	13.7
Natural Gas,	0	0	0	0	0	0	0	0	0
High Sulfur	0	0	0	0	0	0	0	0	0

TABLE 15. EMISSIONS OF OXIDES OF NITROGEN (TONS/YR) BY BOILER SIZE CLASS [a]

Top Number is Potential Emissions (Based on Installed Boiler Capacity); Lower Number is Actual Emissions (Based on Annual Fuel Consumption or Actual Boiler Use)

Fuel	Size 0: 5^+ -10×10^5 Btu/hr			Size 1: 1^+ -2×10^6 Btu/hr			Size 2: 2^+ -5×10^6 Btu/hr			Size 3: 5^6 -10×10^6 Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal	12,324.1	4,402.5	2.5	17,002.7	9,874.3	5.0	50,616.7	43,857.2	65.3	82,074.5	64,730.4	42.7
	3,760.0	1,875.0	0	5,185.7	4,206.8	2.5	15,439.0	18,681.9	30.1	25,032.2	27,574.9	20.1
Pulverized Coal	0	845.8	0	656.2	4,623.4	0	0	7,729.7	0	571.9	7,777.8	0
	0	442.5	0	276.9	2,414.0	0	0	4,051.5	0	243.8	4,075.5	0
Residual Oil	9,206.7	14,121.3	12.3	12,236.0	31,356.5	43.0	53,264.8	161,547.8	98.3	56,603.8	195,660.5	251.7
	208.3	5,195.0	3.1	2,997.8	11,539.5	15.4	13,049.8	59,449.3	36.8	13,868.8	72,003.8	92.1
Distillate Oil	37,584.9	26,654.7	6.2	50,936.7	59,156.1	24.6	81,593.9	122,801.6	171.9	42,909.1	70,526.3	110.5
	7,741.9	8,790.9	0	10,492.3	19,521.9	3.1	16,809.1	40,525.3	24.6	8,839.8	23,274.4	15.4
By-product gas	0	322.9	0	0	1,340.7	0	0	2,350.1	0	0	1,669.0	0
	0	203.3	0	0	845.7	0	0	1,482.6	0	0	1,051.6	0
Natural Gas	5,100.0	12,159.3	2.6	6,890.6	26,983.1	10.5	10,588.2	81,755.7	92.0	10,580.8	78,244.0	205.1
	1,621.9	6,298.6	0	2,191.3	13,977.0	5.3	3,366.9	42,349.1	44.7	3,366.9	40,530.6	97.3

(a) Emission factors are from Reference 13.

TABLE 15. (Continued)

Fuel	Size 4: 1^{+} -2×10^{7} Btu/hr			Size 5: 2^{+} -5×10^{7} Btu/hr			Size 6: 5^{+} -10×10^{7} Btu/hr			Size 7: 1^{+} -2×10^{8} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal	53,816.)	81,351.6	612.4	88,972.0	230,761.9	3,719.8	61,768.6	291,107.3	13,920.5	15,280.1	230.945.0	44,429.5
	16,415.4	34,655.6	293.7	27,135.6	98,304.2	1,782.1	18,840.1	123,476.9	6,669.1	4,661.1	98,256.5	2,080.8
Pulverized Coal	2,733.1	20,862.3	84.3	9,899.9	42.441.0	1,781.9	7,579.2	74,283.8	4,662.5	6,709.3	181,066.6	37,676.2
	1,158.9	10,932.3	36.1	4,199.0	22,237.9	752.5	3,214.7	38,925.3	1,971.6	2,844.5	94,878.2	15,938.0
Residual Oil	70,987.0	200,044.3	865.7	113,823.5	295,989.8	865.7	77,015.8	230,660.3	16,875.8	36,599.5	186,250.8	79,605.1
	17,391.5	73,615.5	319.3	2,787.8	108,923.5	319.3	18,868.5	84,883.8	6,210.6	8,967.0	68,540.5	29,293.9
Distillate Oil	22,332.5	50,532.5	276.3	25,489.0	52,758.4	276.3	16,692.5	30,065.0	3,284.9	11,560.1	30,715.4	19,153.7
	4,600.4	16,675.6	36.8	5,250.8	17,410.7	36.8	3,438.5	9,896.3	426.7	2,382.0	10,167.0	2,489.8
By-product Gas	0	1,008.6	0	0	5,413.5	0	0	9,299.1	0	0	13,888.8	0
	0	635.0	0	0	3,410.8	0	0	5,858.3	0	0	8,749.9	0
Natural Gas	6,725.5	76,716.1	1,286.0	9,513.8	212,337.8	5,128.0	7,748.7	119,800.8	16,202.0	6,124.1	104,756.9	72,932.0
	2,138.8	39,739.0	610.0	3,051.6	114,592.9	2,429.9	2,464.2	62,056.4	7,679.0	1,891.7	54,302.1	34,568.7

TABLE 15. (Continued)

Fuel	Size 8: 2^{+} -$5x10^{8}$ Btu/hr			Size 9: 5^{+} -$10x10^{8}$ Btu/hr			Size 10: 1^{+} -$2x10^{9}$ Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal	9,615.8	113,163.4	41,422.5	0	27,788.2	7,542.6	0	40,207.7	930.851.1
	2,931.7	48,207.1	19,841.6	0	7,447.2	3,611.9	0	23,320.0	400,119.1
Pulverized Coal	0	200,372.7	310,881.8	0	99,396.2	507,919.4	0	48,217.2	1,116,279.6
	0	104,994.8	131,500.9	0	57,647.5	214,850.8	0	27,965.9	479,824.1
Residual Oil	22,765.8	151,697.0	299,037.4	7,365.8	52,977.8	341,712.5	0	30,537.5	350,326.9
	5,577.3	55,825.0	84,286.9	1,804.3	19,495.0	175,496.6	0	11,238.5	177,783.7
Distillate Oil	10,966.0	16,388.0	64,313.4	3,585.2	4,685.0	66,726.5	0	0	12,676.0
	2,259.8	5,408.8	8,359.6	738.8	1,545.4	8,675.8	0	0	1,648.6
By-product Gas	0	14,711.8	3,934.2	0	12,696.9	0	0	4,298.2	0
	0	9,272.3	2,477.3	0	7,999.0	0	0	2,708.3	0
Natural Gas	5,299.4	75,452.1	284,757.4	1,223.8	37,386.7	445,017.4	2,759.8	35,339.0	638,044.7
	1,679.7	39,084.0	134,974.5	388.9	19,366.0	210,936.0	877.8	18,301.4	302,453.3

TABLE 15. (Continued)

Fuel	Size 11: 2^{+} -5×10^{9} Btu/hr			Size 12: 5^{+} -10×10^{9} Btu/hr			Size 13: 1^{+} -2×10^{10} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal	0	19,076.0	15,391.3	0	0	0	0	0	0
	0	5,112.9	7,371.9	0	0	0	0	0	0
Pulverized Coal	0	36,105.0	1,139,393.4	0	15,254.7	984,336.2	0	0	67,622.7
	0	20,853.3	481,964.2	0	8,846.4	416,373.3	0	0	28,604.0
Residual Oil	0	5,285.0	395,680.0	0	0	82,601.4	0	0	0
	0	1,944.3	215,108.8	0	0	53,442.6	0	0	0
Distillate Oil	0	4,275.1	8,761.8	0	0	15,914.9	0	0	40,124.9
	0	1,410.0	1,139.0	0	0	2,069.2	0	0	5,215.9
By-product Gas	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0
Natural Gas	1,150.2	22,172.4	652,219.0	0	29,885.4	268,016.1	4,533.3	47,208.9	28,877.8
	365.7	11,101.6	309,151.0	0	15,480.4	127,040.4	1,441.5	24,454.3	13,651.3

TABLE 16. PARTICULATE EMISSIONS (TONS/YR) BY BOILER SIZE CLASS[a]

Top Number is Potential Emissions (Based on Installed Boiler Capacity); Lower Number is Actual Emissions (Based on Annual Fuel Consumption or Actual Boiler Use)

Fuel	Size 0: 5^{+} -10×10^{5} Btu/hr			Size 1: 1^{+} -2×10^{6} Btu/hr			Size 2: 2^{+} -5×10^{6} Btu/hr			Size 3: 5^{+} -10×10^{6} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal, Low Sulfur	78,505.5	13,203.7	0	108,310.	21,388.2	0	435,732.3	0	0	746,822.1	168,009.8	0
	23,952.1	5,623.8	0	33,033.2	9,112.0	0	132,921.7	0	0	226,113.5	71,574.2	0
Stoker Coal, High Sulfur	23,261.6	7,535.1	16.3	32,091.7	27,462.5	32.6	64,219.7	183,311.6	636.1	80,680.6	249,617.9	0
	7,096.4	3,208.4	0	9,787.8	11,699.8	16.3	19,588.1	78,086.3	361.3	24,606.9	106,336.	0
Pulverized Coal, Low Sulfur	0	4,511.7	0	29.2	24,662.0	0	0	31,989.6	0	6,355.5	297.3	0
	0	2,360.2	0	12.3	12,876.9	0	0	16,766.5	0	2,709.5	155.8	0
Pulverized Coal, High Sulfur	0	1,879.9	0	0	10,275.8	0	0	21,713.7	0	0	29,561.1	0
	0	655.6	0	0	5,365.4	0	0	11,381.8	0	0	15,489.6	0
Residual Oil	3,535.4	5,421.0	1.0	4,698.6	12,040.9	3.3	20,453.7	62,034.3	7.8	21,735.8	75,133.6	19.2
	866.2	1,995.2	0.2	1,151.1	4,431.2	1.2	5,011.1	22,828.5	2.8	5,325.6	27,649.4	7.0
Distillate Oil	9,388.2	6,653.7	0.2	12,723.3	14,776.4	1.0	20,381.1	30,674.3	13.1	10,718.1	17,616.6	8.4
	1,933.8	2,195.8	0	2,620.8	4,876.3	0	4,198.7	10,122.7	1.9	2,208.0	5,813.6	1.2
Natural Gas	968.8	1,250.8	0.1	1,308.9	2,775.6	0	2,011.3	8,410.	2.3	2,009.9	8,048.8	5.1
	308.0	647.9	0	416.2	1,437.8	0	639.6	4,356.4	1.1	639.1	4,169.3	2.4
By-product Gas	0	33.2	0	--	--	--	--	--	--	--	--	--
	0	20.9	0	--	--	--	--	--	--	--	--	--

(a) Emission factors are from Reference 13.

TABLE 16. (Continued)

Fuel	Size 4: 1^{+} -2×10^{7} Btu/hr			Size 5: 2^{+} -5×10^{7} Btu/hr			Size 6: 5^{+} -10×10^{7} Btu/hr			Size 7: 1^{+} -2×10^{8} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal,	229,824.4	187,377.2	1,612.8	356,491.1	423,332.3	6,703.3	170,974.7	734,105.4	52,814.9	30,588.5	684,726.6	107,392.1
Low Sulfur	70,101.5	79,822.7	774.2	108,725.6	180,339.0	3,211.6	52,147.8	311,381.0	25,303.3	9,329.5	291,691.5	5,029.0
Stoker Coal,	183,014.5	320,570.8	2,961.2	325,679.6	1,155,661.3	20,272.4	261,150.4	1,334,784.8	40,220.3	74,743.6	928,134.2	224,567.8
High Sulfur	55,823.9	136,423.4	1,419.0	99,529.9	492,309.5	9,712.	79,654.4	566,165.8	19,268.4	22,799.5	395,382.6	10,517.9
Pulverized Coal,	0	107,597.1	281.	47,712.4	98,881.3	8,496.3	65,142.8	138,229.7	5,245.1	31,971.5	409,667.8	54,429.8
Low Sulfur	0	56,383.7	120.4	20,236.6	51,811.0	3,588.2	6,422.4	72,434.6	829.2	13,555.3	214,665.2	23,027.
Pulverized Coal,	18,223.6	40,550.3	468.3	21,347.5	199,584.3	6,416.4	36,261.3	477,875.4	27,095.6	19,844.6	1,001,139.5	371,549.1
High Sulfur	7,727.	21,248.7	200.7	9,054.6	104,576.5	2,709.5	15,392.7	250,409.4	11,458.5	8,412.1	52,463.7	157,176.
Residual Oil	27,259.	76,817.0	65.9	43,708.2	111,660.1	65.9	29,574.0	88,969.1	1,284.6	14,054.2	71,520.3	6,059.8
	6,678.3	28,268.4	24.3	1,070.5	41,826.6	24.3	7,218.6	32,595.4	472.8	3,443.4	26,319.6	2,230.
Distillate Oil	5,578.4	12,622.4	21.0	6,366.8	13,178.4	21.0	4,169.6	7,509.8	250.1	2,887.6	7,695.8	1,458.1
	1,149.1	4,165.4	2.8	1,311.6	4,349.0	2.8	858.9	2,472.	32.5	595.0	2,539.6	189.5
Natural Gas	1,275.9	7,891.7	32.1	1,807.2	21,842.8	128.1	1,471.9	12,323.7	404.8	1,163.3	10,776.2	1,822.1
	406.3	4,087.9	15.2	579.7	11,788.	60.7	468.1	6,383.6	191.8	359.3	5,585.3	863.6
By-product Gas	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 16. (Continued)

Fuel	Size 8: 2^+ -$5x10^8$ Btu/hr			Size 9: 5^+ -$10x10^8$ Btu/hr			Size 10: 1^+ -$2x10^9$ Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal, Low Sulfur	26,046.2 7,940.2	285,825.7 121,760.5	43,066.7 20,629.2	0 0	601.9 161.3	19,604.9 9,388.2	0 0	93,081.6 24,944.7	0 0
Stoker Coal, High Sulfur	77,897.8 23,751.0	542,094.0 230,929.4	259,665.0 124,380.3	0 0	164,320.4 44,038.1	49,012.3 23,171.5	0 0	46,560.3 12,477.3	84,894.8 40,666.9
Pulverized Coal, Low Sulfur	0 0	400,048.2 209,624.8	414,579.3 175,365.0	0 0	222,011.7 128,761.2	650.243.9 275,053.7	0 0	93,235.2 54,076.6	1,296,290.8 557,200.3
Pulverized Coal, High Sulfur	0 0	1,218,977.7 638,740.9	3,071,355.5 1,299,359.5	0 0	593,455.2 344,190.7	4,722,404.8 1,997,586.0	0 0	266,310.5 154,459.4	1,026,902.3 4,739,829.6
Residual Oil	8,742.0 2,141.7	58,251.6 21,436.8	17,435.2 6,416.2	2,828.4 692.8	20,343.5 7,486.1	26,012.4 13,359.4	0 0	11,726.4 4,315.6	26,668.2 13,533.6
Distillate Oil	2,739.2 564.5	4,093.5 1,351.0	4,895.8 636.4	895.5 184.6	1,170.2 386.0	5,079.5 660.0	0 0	0 0	964.9 125.5
Natural Gas	1,006.6 319.1	7,761.6 4,020.5	7,114.1 3,372.0	232.5 73.9	3,845.9 1,992.1	11,117.8 5,269.8	524.2 166.7	3,634.4 1,882.6	15,940.2 7,556.2
By-product Gas	--	--	--	--	--	--	--	--	--

TABLE 16 (Continued)

Fuel	Size 11: 2^{+} -5×10^{9} Btu/hr			Size 12: 5^{+} -10×10^{9} Btu/hr			Size 13: 1^{+} -2×10^{10} Btu/hr		
	Com.	Ind.	Utility	Com.	Ind.	Utility	Com.	Ind.	Utility
Stoker Coal,	0	0	0	0	0	0	0	0	0
Low Sulfur	0	0	0	0	0	0	0	0	0
Stoker Coal,	0	206,596.5	166,690.8	0	0	0	0	0	0
High Sulfur	0	55,373.3	79,838.7	0	0	0	0	0	0
Pulverized Coal,	0	0	2,165,205.8	0	0	2,734,721.5	0	0	0
Low Sulfur	0	0	915,884.4	0	0	1,156,784.6	0	0	0
Pulverized Coal,	0	401,232.8	10,444,953.1	0	305,144.3	9,155,847.5	0	0	1,052,082.8
High Sulfur	0	231,741.6	4,418,224.6	0	176,957.2	3,872,914.9	0	0	445,025.5
Residual Oil	0	2,029.4	30,120.7	0	0	6,287.9	0	0	0
	0	746.6	16,374.9	0	0	4,068.2	0	0	0
Distillate Oil	0	1,067.9	647.0	0	0	1,211.5	0	0	3,054.5
	0	352.2	86.7	0	0	157.5	0	0	397.0
Natural Gas	218.5	2,280.8	16,293.1	0	3,074.3	6,695.8	861.1	4,856.3	721.5
	69.5	1,142.0	8,099.1	0	1,592.4	3,173.8	273.8	2,515.6	341.0
By-product Gas	--	--	--	-	--	--	--	--	--

TABLE 17. SULFUR DIOXIDE EMISSIONS (TONS/YR) FROM RESIDENTIAL UNITS AS A FUNCTION OF FUEL TYPE AND DESIGN SIZE CLASS

Top Number is Potential Emissions (Based on Total Installed Capacity), Lower Number is Actual Emissions (Based on Annual Fuel Consumption or Actual Boiler Use)

Fuel	Design Firing Rate				
	2^{+}-5 x 10^{4}	5^{+}-10 x 10^{4}	1^{+}-2 x 10^{5}	2^{+}-5 x 10^{5}	5^{+}-10 x 10^{5}
Distillate oil[(a)] and kerosine	--	443,241	693,768	138,598	70,078
	--	88,651	138,754	27,720	14,016
Natural gas	Nil	Nil	Nil	Nil	Nil
	Nil	Nil	Nil	Nil	Nil
LPG	Nil	Nil	Nil	Nil	Nil
	Nil	Nil	Nil	Nil	Nil

(a) Distillate oil and kerosine emission factors taken from Reference 14.

TABLE 18. NO_x EMISSIONS (TONS/YR) FROM RESIDENTIAL UNITS AS A FUNCTION OF FUEL TYPE AND DESIGN SIZE CLASS

Top Number is Potential Emissions (Based on Total Installed Capacity), Lower Number is Actual Emissions (Based on Annual Fuel Consumption or Actual Boiler Use

Fuel	Design Firing Rate				
	2^{+}-5 x 10^{4}	5^{+}-10 x 10^{4}	1^{+}-2 x 10^{5}	2^{+}-5 x 10^{5}	5^{+}-10 x 10^{5}
Distillate oil[(a)] and kerosine	--	275,313	430,925	86,088	43,528
	--	56,062.	86,185	17,218	8,706
Natural gas[(b)]	15,540	679,056	86,688	69,300	34,020
	3,108	137,383	17,338	13,860	6,804
LPG[(b)]	--	91,177	35,784	--	--
	--	18,236	7,157	--	--

(a) Distillate oil and kerosine emission factors taken from Reference 14.
(b) Natural gas and LPG emission factors taken from Reference 15.

TABLE 19. PARTICULATE EMISSIONS (TONS/YR) FROM RESIDENTIAL UNITS AS A FUNCTION OF FUEL TYPE AND DESIGN SIZE CLASS

Top Number is Potential Emissions (Based on Total Installed Capacity), Lower Number is Actual Emissions (Based on Annual Fuel Consumption or Actual Boiler Use)

Fuel	Design Firing Rate				
	2^{+}-5 x 10^{4}	5^{+}-10 x 10^{4}	1^{+}-2 x 10^{5}	2^{+}-5 x 10^{5}	5^{+}-10 x 10^{5}
Distillate oil[(a)] and kerosine	--	34,414	53,866	10,761	5,441
	--	6,883	10,773	2,152	1,088
Natural gas[(b)]	3,078	134,318	17,172	13,728	6,739
	616	26,910	3,434	2,746	1,348
LPG[(b)]	--	18,062	7,089	--	--
	--	3,612	1,418	--	--

(a) Distillate oil and kerosine emission factors taken from Reference 14.
(b) Natural gas and LPG emission factors taken from Reference 13.

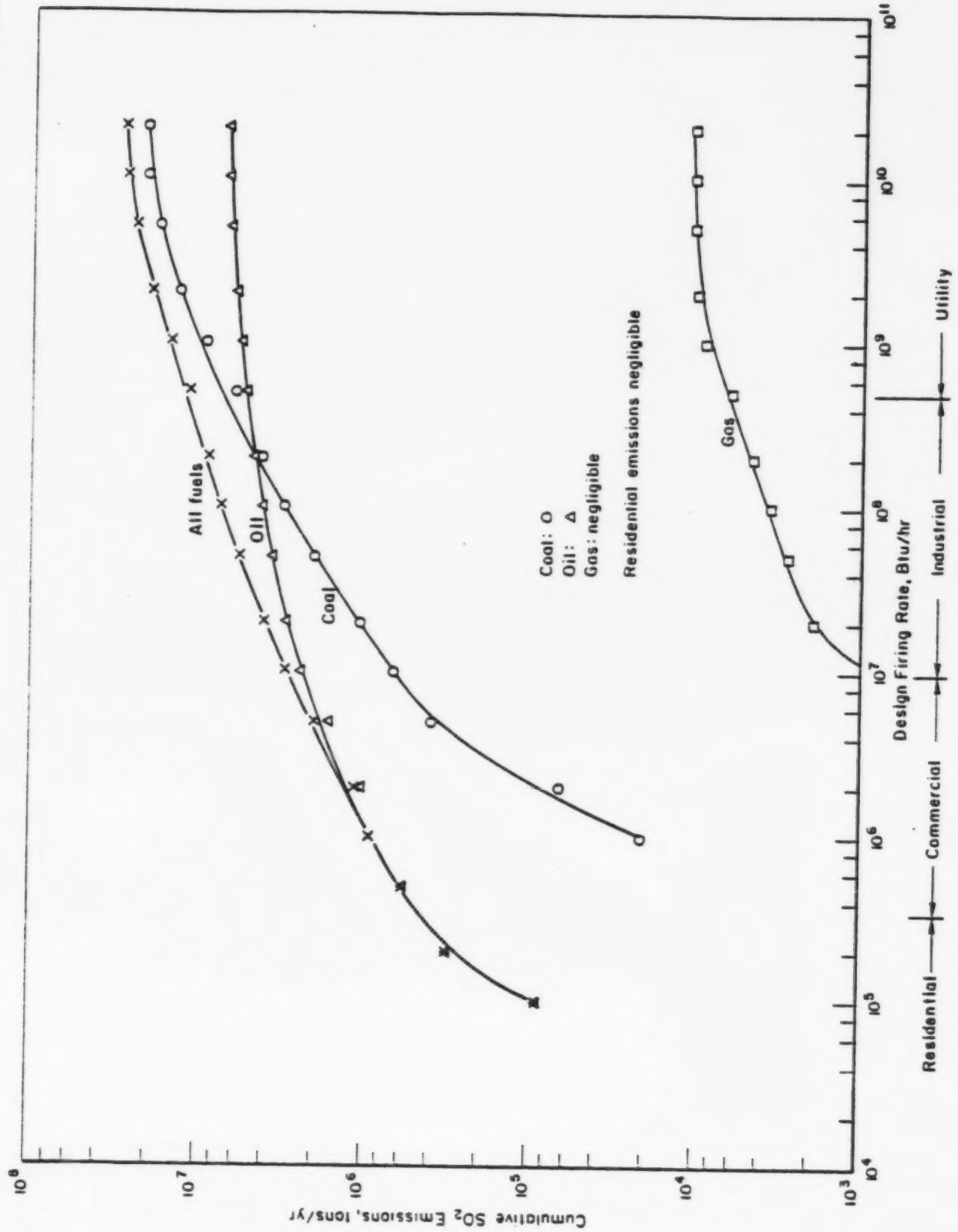

FIGURE 7. CUMULATIVE SO_2 EMISSIONS FOR ALL BOILERS BASED ON ACTUAL BOILER USE

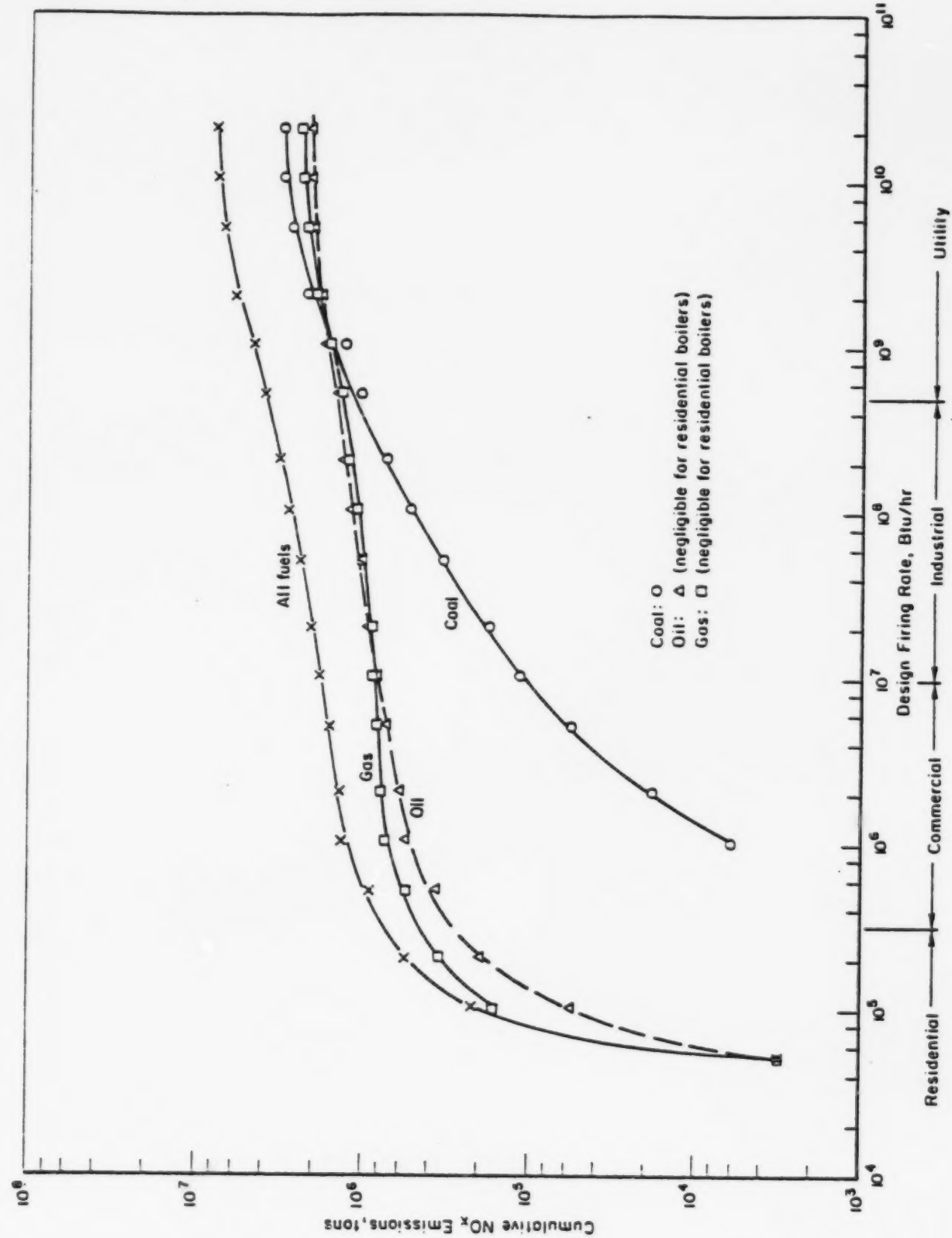

FIGURE 8. CUMULATIVE NO_x EMISSIONS FOR ALL BOILERS BASED ON ACTUAL BOILER USE

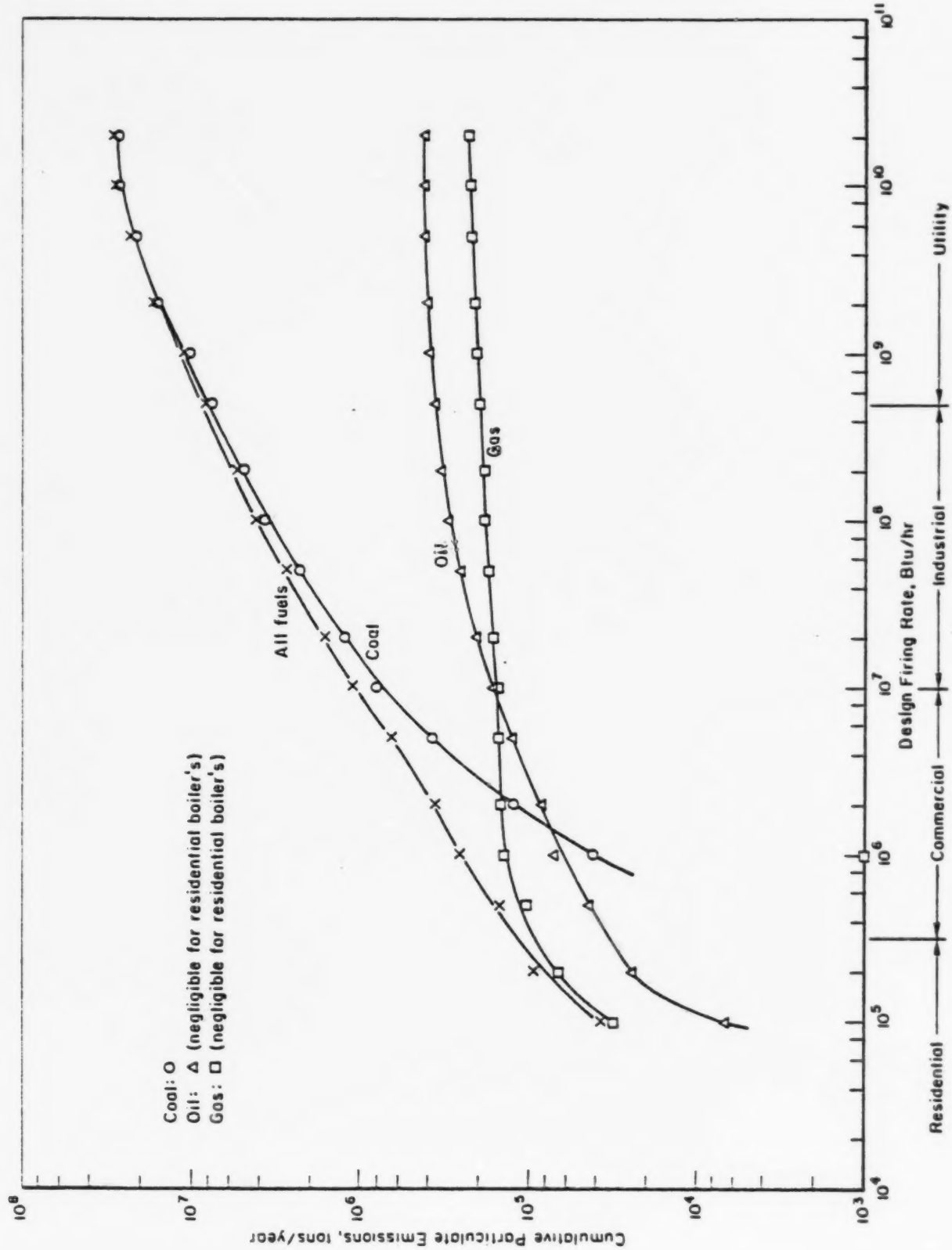

FIGURE 9. CUMULATIVE PARTICULATE EMISSIONS FOR ALL BOILERS BASED ON ACTUAL BOILER USE

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(2) National Emiss[illegible]ta System (NEDS), National Source Inventory Section, Envir[illegible]l Protection Agency, Durham, N.C.

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(6) American Boiler Manufacturing Association (a) Stationary Watertube Steam and Hot-Water Generating Sales (Year); (b) Data Compilations on Watertube Boilers; (c) Data Compilation on Firetube Boilers.

(7) Steel Power Boiler Report, Series MA-34G (Year)-1, from 1962 through 1971, Bureau of Census, U.S. Department of Commerce.

(8) Paddock, R. E., and McMann, D. C., "Distribution of Industrial and Commercial--Institutional External Combustion Boilers", Research Triangle Institute Report to Environmental Protection Agency (Contract No. 68-02-1325, Task 5), February, 1975.

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(10) U.S. Department of the Interior, Bureau of Mines, 1972 U.S. Energy Use, News Release, March 10, 1973.

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APPENDIX A-1

DISTRIBUTION OF BOILER POPULATION

The simplest way to determine the distribution of the various fuel firing methods for the boilers included in the ABMA data (by use of the NEDS distribution) is to determine a factor P from

$$PQ^* = Q_g + Q_d + Q_r,$$

where Q^* is the total ABMA design firing capacity (for all fuels) in size range s and Q_g, Q_d, Q_r are the total installed capacities from NEDS (for gas, distillate oil, and residual oil-fired boilers, respectively) in the same size range. Then the total design firing rate for gas-fired boilers, $Q_g^* = Q_g/P$, and so forth for distillate and residual oil. This approach assumes that the fraction of boilers not counted by NEDS depends only on the design firing rate. That is, the NEDS data does not preferentially count boilers firing any one fuel.

A second method is to assume that the chance of observing a boiler is related to its actual firing rate. If a linear relation is assumed, one might include the annual load factors (ALF) in the relation

$$P'Q^* = Q_g/ALF_g + Q_d/ALF_d + Q_r/ALF_r$$

to determine P' where ALF_g, ALF_d, and ALF_r are annual load factors for gas, distillate oil, and residual oil-fired boilers, respectively. Then $Q_g^* = Q_g/P'\ ALF_g$, and so forth.

Finally, one might assume that the pollutant itself would have an effect on the probability of observation. It would appear that the only way to approach this problem would be to assume that P is a function of (s x function ALF) and fuel. If Q is plotted for each fuel as a function of s, then the curves could be shifted horizontally and vertically to match shapes. Assuming that this is the only factor involved, then the horizontal shift could be expressed as a numerical factor for each fuel. This factor could be used to replace ALF in the treatment outlined above, and values of P' determined for each size range.

Figure A-1 through A-6 present the normalized NEDS count on design firing rate obtained from Table 5, using the normalizing ratio from Table 1. It is interesting to note that the slope at the lower capacities tends to be about 2:1 when there is a change in use, as for example, in the case of the utility boilers. On the other hand, when there is reason to believe that boilers are being missed because of low capacity, low firing rate, and low pollution level, the slope tends to be 1:1 as in the case of the commercial boiler firing oil (distillate plus residual). It is also apparent that the peaks of the curves for commercial, industrial, and utility boilers occur at progressively higher design firing rates, as expected.

These figures were basically prepared to enable a choice to be made among the three methods outlined above, to determine multiplying factors to convert NEDS data at low design capacities to an equivalent number basis with ABMA data. However, an examination of the curves failed to show any particular consistency that would permit a choice. Therefore, the simplest method, the first outlined, was used. The multiplying factor was determined from the ratio of the curves shown in Figure 2. The multiplying factor as a function of size is presented in Figure 1. Because of the apparent lack of influence of type of fuel or principal pollutant on this factor, it was not felt that a previous assumption made in Reference 1, that all the coal-fired units down to some low size were counted, could be made. Rather, the coal-fired units were determined by use of the same multiplying factor as determined from the gas and oil data.

It should be noted that the assumption is made that all utility units are counted in NEDS.

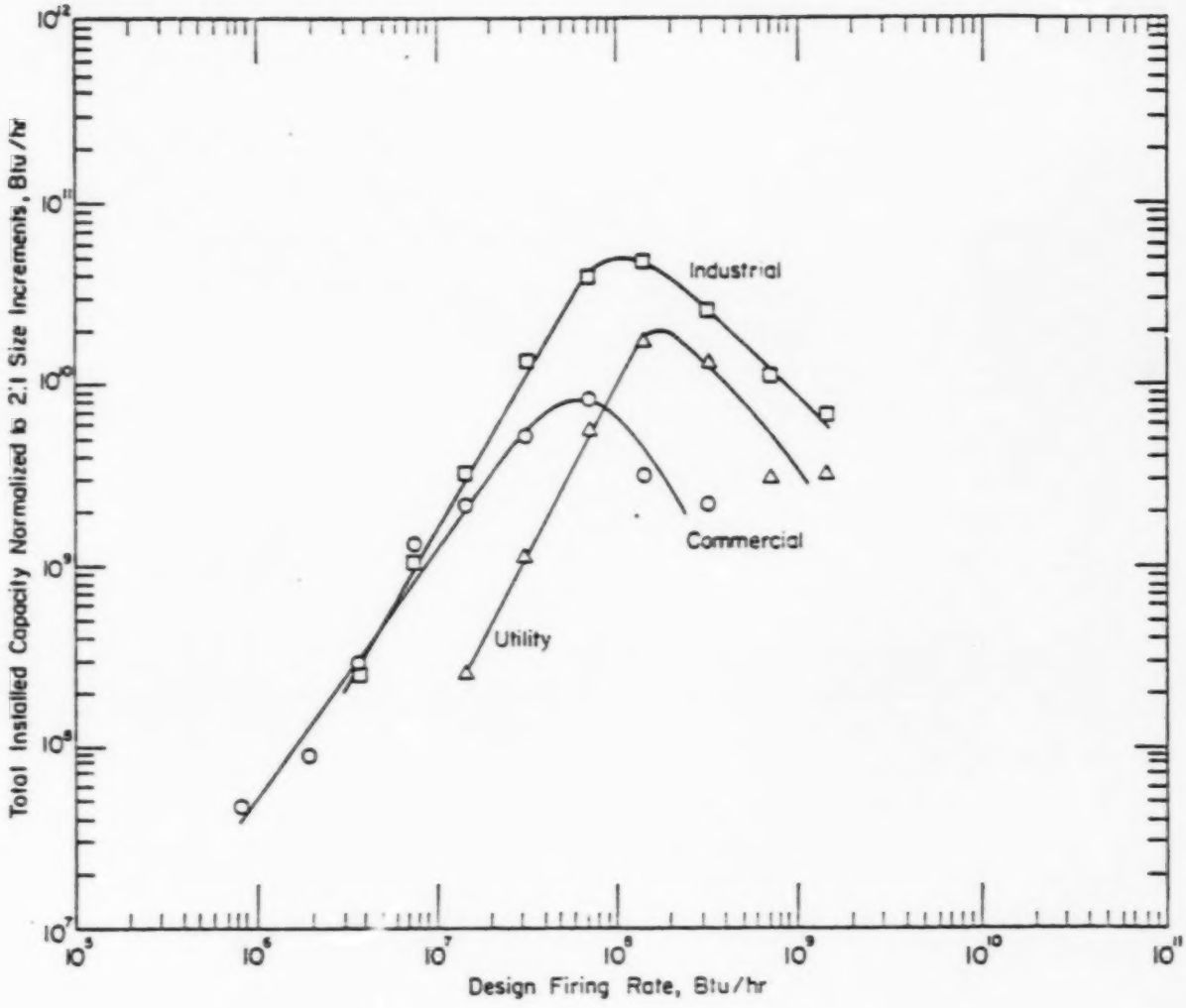

FIGURE A-1. TOTAL INSTALLED CAPACITY OF STOKER-FIRED BOILERS NORMALIZED FROM NEDS DATA

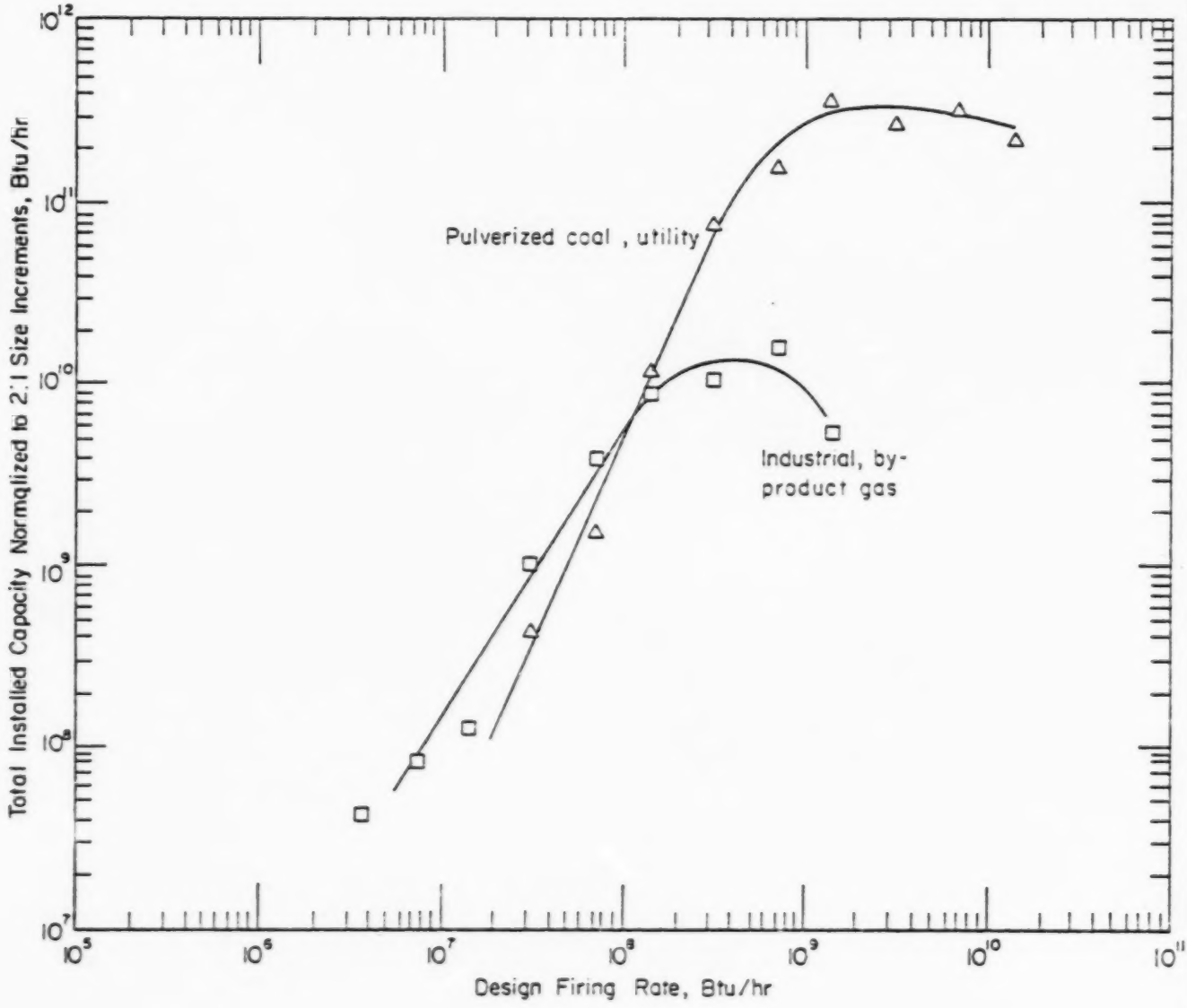
Total Installed Capacity Normalized to 2:1 Size Increments, Btu/hr
Design Firing Rate, Btu/hr
Pulverized coal , utility
Industrial, by-product gas

FIGURE A-2. TOTAL INSTALLED CAPACITY OF PULVERIZED COAL-AND BY-PRODUCT GAS-FIRED BOILERS FROM NEDS DATA

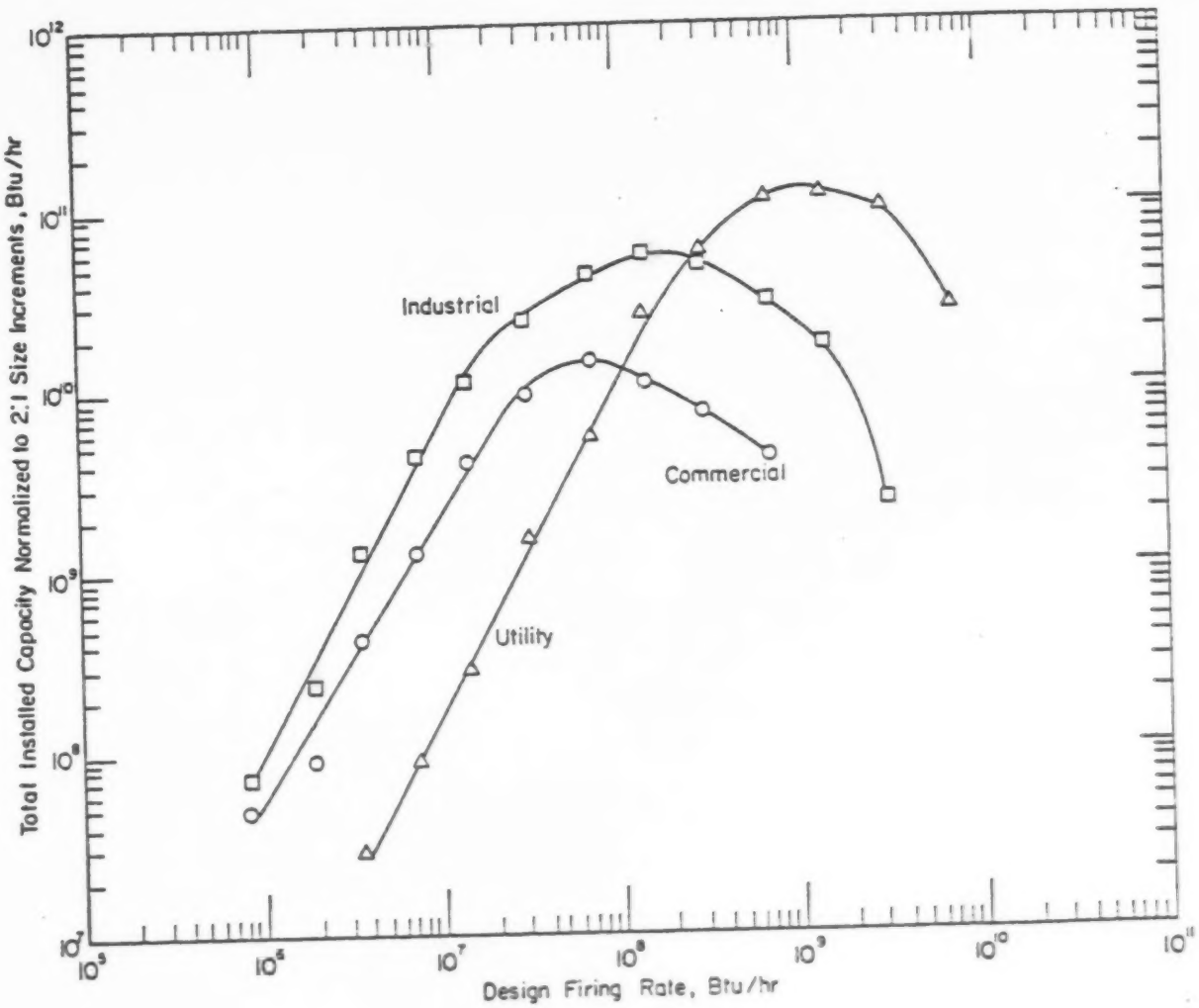

FIGURE A-3. TOTAL INSTALLED CAPACITY OF RESIDUAL OIL-FIRED BOILERS NORMALIZED FROM NEDS DATA

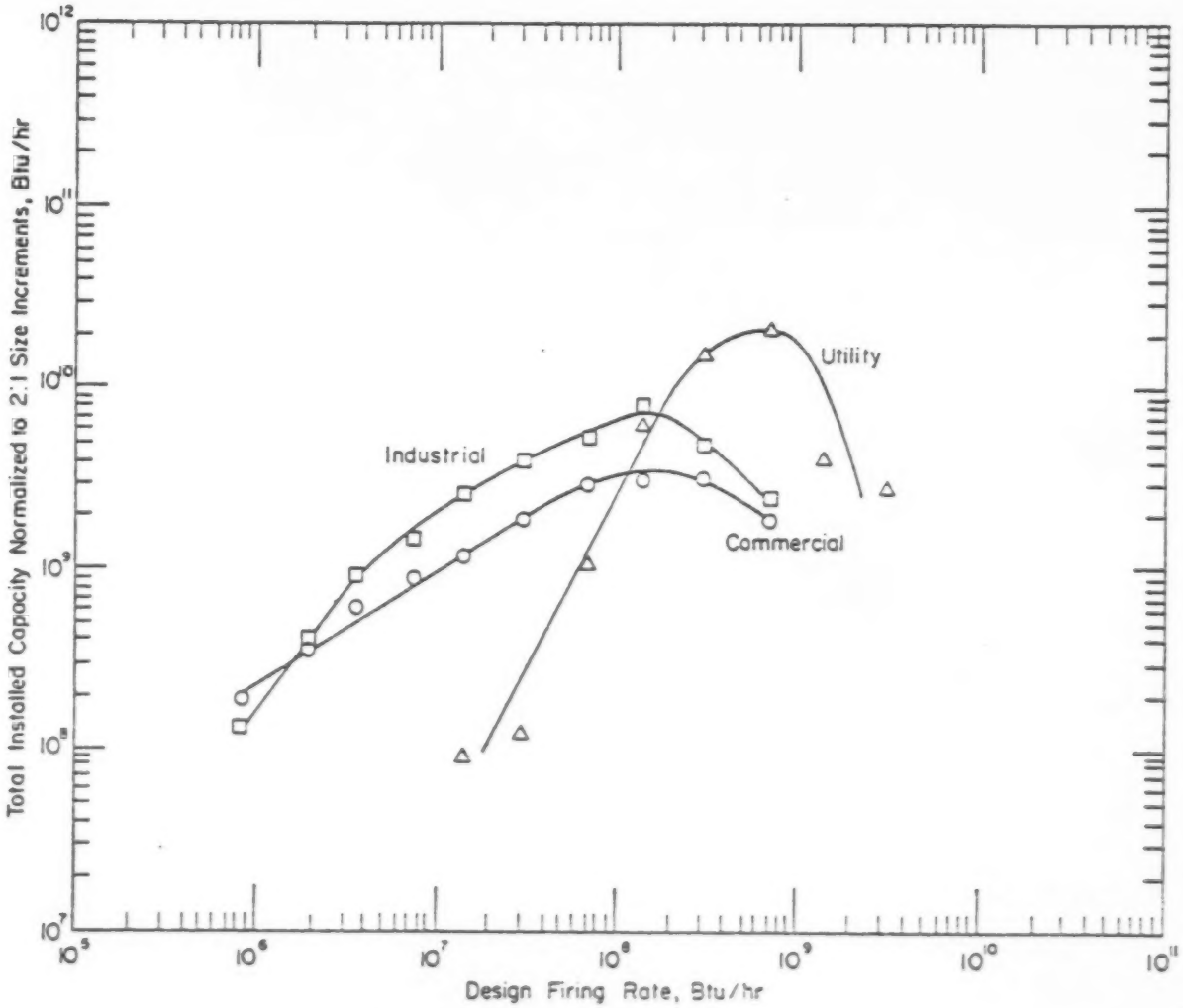

FIGURE A-4. TOTAL INSTALLED CAPACITY OF DISTILLATE OIL-FIRED BOILERS NORMALIZED FROM NEDS DATA

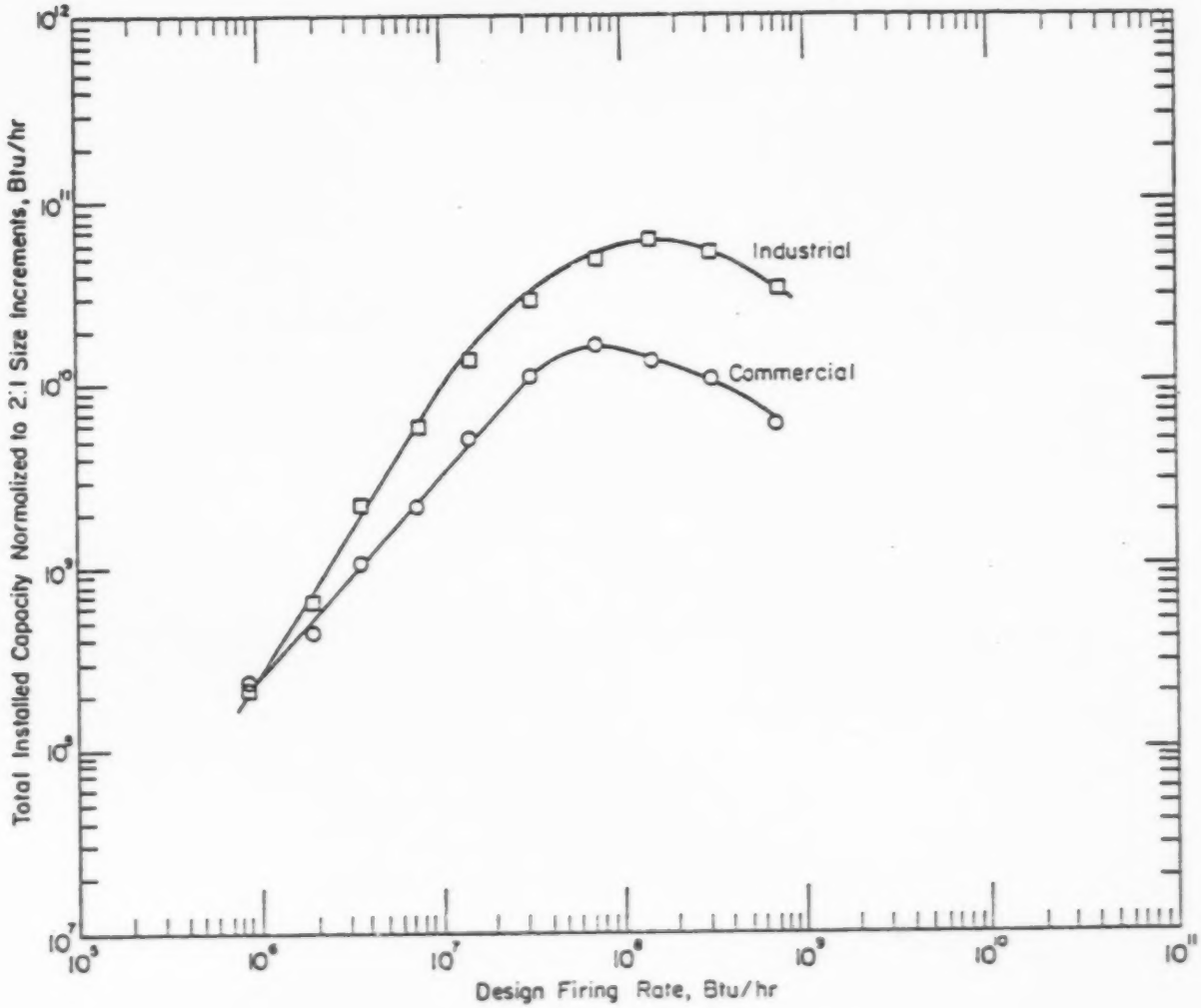

FIGURE A-5. TOTAL INSTALLED CAPACITY OF DISTILLATE AND RESIDUAL OIL-FIRED BOILERS, NORMALIZED FROM NEDS DATA

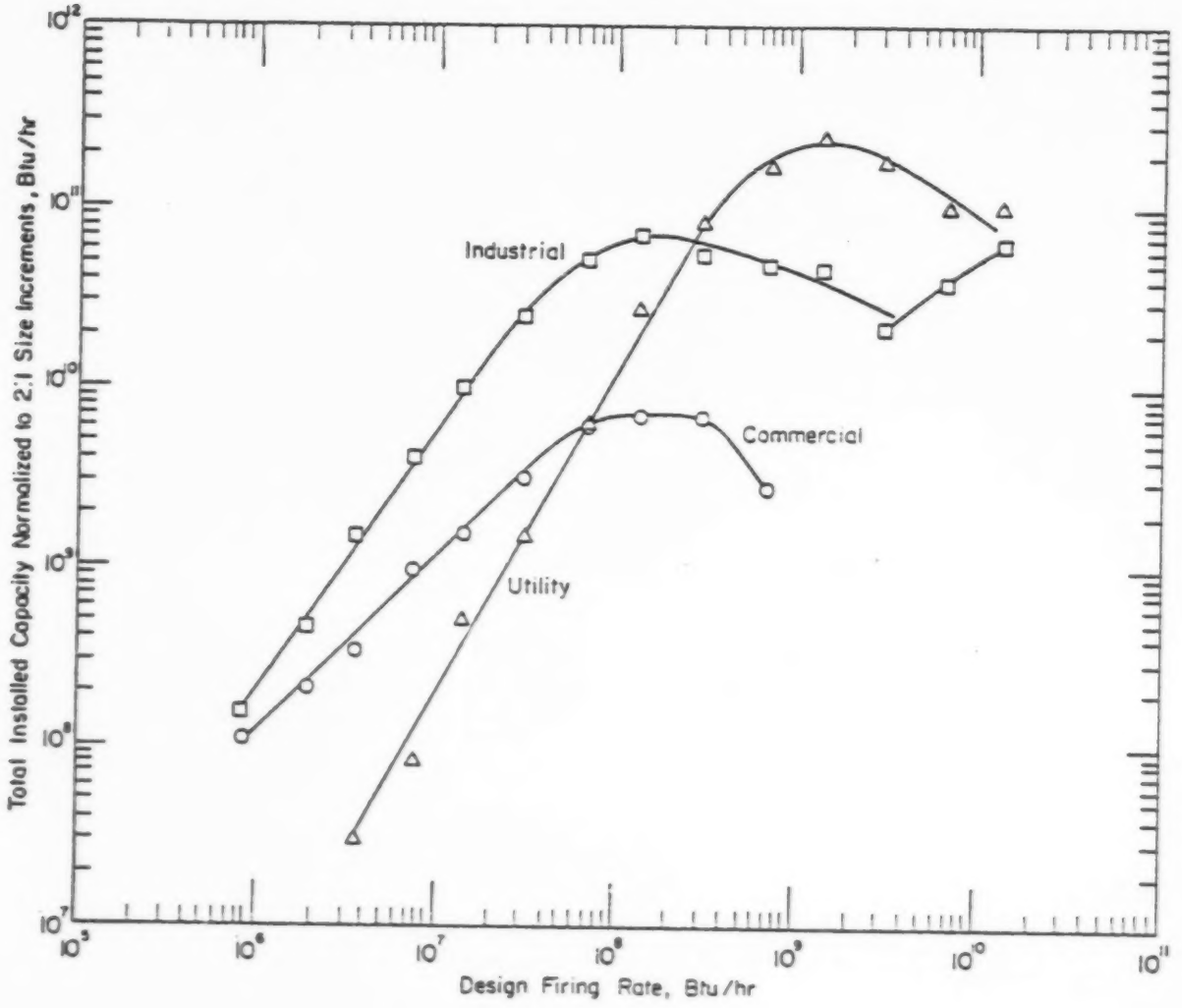

FIGURE A-6. TOTAL INSTALLED CAPACITY OF NATURAL GAS-FIRED BOILERS, NORMALIZED FROM NEDS DATA

APPENDIX B-1

COMPILATION OF BOILER POPULATION FOR SMALL BOILERS

The number of water-tube boilers below 10^7 Btu/hr is estimated as a constant function of 0.066 of those in the range 1^+ - 10 x 10^7 Btu/hr. This is based on the data in Reference 7. The entire capacity, computed from the data of Reference 1 corrected for hot-water boilers, of 88.7 x 10^9 Btu/hr is assumed to be in the range 5^+ - 10 x 10^6 Btu/hr.

Fire-Tube Boilers in Small Sizes

Neither Reference 6 nor Reference 7 report all fire-tube boiler sales. However, it is believed that Reference 6 includes a known fraction (85 percent) of Scotch boilers. A comparison of the ratio of the total sales (based on design firing rates) of Scotch boilers over a period of years (1965-1971) from Reference 6 and 7 shows that there is little variation from 0.55. That is, Reference 7 consistently reports only 55 percent of the Scotch boiler sales that are reported in Reference 6. Thus the data from the two sources are proportional if not equal. The data from Reference 7 on the total sales of all fire-tube boilers compared to Scotch boiler sales gives a ratio of 1.26, with little variation from 1962 through 1972. Thus, to determine the total sales of fire-tube boilers in 1971 for a given size range, assuming the above factors are not a function of size (this assumption could not be checked), the sales of Scotch boilers in that range (according to ABMA data, Reference 6) can be multiplied by 1.26/0.85, where 0.85 corrects the ABMA data for the estimated fraction missed in the compilation[1].

The ABMA sales data for Scotch boilers were examined for design firing rates down to 5 x 10^5 Btu/hr, in the increments shown in Table B-1. These data covered 1965 through 1972. It was noted that, as the design firing rate becomes less, the rate of sales increase becomes less, and eventually reverses. The rate of sales was determined for each size class, and combined with the observation in the Walden report[9] that

10 percent of the boilers were more than 24 years old to determine a mean life. Combining these factors, it was possible to determine the ratio of the Scotch boiler population in each size class to that in the 1 - 2 x 10^7 Btu/hr size range. (These values are tabulated in Table B-1.) The product of this term, 1.26, and the reference Scotch-boiler installed capacity in the 1^+ to 2 x 10^7 Btu/hr size range (corrected for missing data) gives the installed capacity of fire-tube boilers for each size range. The total fire-tube boilers installed capacities for small boiler sizes are given in Table B-1.

Adding the water-tube boiler installed capacity in the 5^+ - 10 x 10^6 Btu/hr size class gives the total installed capacity for all boilers in the 5 x 10^5 to 10 x 10^6 Btu/hr size ranges. The total installed capacities for various sizes of small fire-tube and water-tube boilers are listed in the last column of Table B-1.

TABLE B-1. DATA ON SMALL BOILERS
5 x 10^3 to 10 x 10^5
Btu/hr Firing Rates

Firing Rate Design, Btu/hr	Design Size, hp	(Scotch Boilers in Size Range of Interest) / (Scotch Boilers in 1^+ -2x10^7 Btu/hr, Size Range)	Total Fire-Tube Boiler Installed Capacity, 10^9 Btu/hr	Total Boiler Installed Capacity, 10^7 Btu/hr
5 x 10^5	15	0.022	5.7	5.7
5^+ - 10 x 10^5	20, 25, 30	0.286	74.2	74.2
1^+ - 2 x 10^6	40, 50, 60	0.390	101.2	101.2
2^+ - 5 x 10^5	70 - 150	1.328	344.6	344.6
5^+ - 10 x 10^5	200, 250, 300	1.161	301.2	389.9